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FOR THE

PROMOTION OF THE MECHANIC ARTS.

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EDITORIAL.

NOTICE.—The publication of the JOURNAL is made under the direction of the Editor and the Committee of Publication, who endeavor to exercise such supervision of its articles, as will prevent the inculcation of errors or the advocacy of special interests, and will produce an instructive and entertaining periodical; but it must be recognized that the Franklin Institute is not responsible, as a body, for the statements and opinions advanced in its pages.

The Use of Steam Carriages on the Street Railways and Common Roads.—In none of the appliances of the steam engine, since it was emancipated from the patents and the practice of James Watt, in the year 1800, has so little accomplishment resulted from so much ingenuity and effort, as has been expended upon the use of steam as a means of transport in the ordinary avocations of life. The very earliest attempts at locomotion were made upon common roads, and so far as *movement on these* has been effected, the success attained nearly seventy years since by Trevithic has scarcely been equaled, and certainly has not been far surpassed down to the present time, notwithstanding the great advance in the knowledge of the properties of steam, and in the facilities for construction. The essays have numbered by the hundreds. Experienced mechanics, with skilled labor applied in the direction of thorough knowledge of mechanism and of the

steam engine, have vied with inventive projectors who have possessed that ignorance, which, untrammeled by *educated* notions to unlearn, sometimes gives scope to ingenuity and novelty; and both knowledge and invention have failed alike.

Within the past few years there has been put in use in England, as a means of hauling heavy weights, the form of engine known as a Traction Engine, and as the roads of that land are (and from the absence of frost can be) kept in excellent order, and as the quantity of heavy material to be removed is very great, these engines have increased, and still continue to increase, in number. Another class of engine in England, but little known in the United States, the Agricultural Engine, which is a power engine of small size, with its boiler mounted on wheels, to be moved from place to place, has also been made to be self-propelling. The Road Roller is another type of locomotive which has been quite fully introduced. None of these answer the description of steam carriages, nor does the kind of engine likely to grow from them, promise much towards a Darwinian development into what will eventually be found to be employed in transporting passengers and light loads in the street, whether on the rails or on the pavement.

The mechanical difficulties to the application of steam as a motive power for carriages, have gradually come to be appreciated, and with the somewhat more complete knowledge of the conditions and requirements, it is probable that the next attempts, made in earnest, by skilled and informed mechanics, will effect more satisfactory results. It is a settled conclusion that the adhesion of the wheels, or of a pair of them, sustaining half the load, is ample for the purpose of impulsion at any grades practicable for ordinary road use, only noticing that the contact or bearing of the drivers upon the ground must be positive and uniform. A four wheeled vehicle with axles attached to a rigid body, when standing or running on the uneven—generally twisted—surface of a road, will obviously rest or have its bearing only upon three of its wheels, and this condition of three points of bearing attaches to the tram road locomotive, as well as to the common road one. Balance bars or gimbal-hung swinging axles will secure the equal distribution of weight upon drivers, or what in the road carriages is equally essential, on directing wheels. The possibility of *driving* around any curve, as the directing wheels may lead or trail, is secured by the "jack-in-the-box motion" of the traction engine,

which applies the force to either driver of a pair of wheels, imparting to either wheel in whatever proportion is requisite, the motion or rotation it should have when running upon a curved line. Of course, the abrading action of the tires (like that of the faces of a mortar mill) upon the ground, yet remains, and the wear on them, and on the road bed at the place of turning, will still be large, but the leverage to overcome this grinding, and the amount of grinding, will be so much less, than that which accompanied the action of wheels rigidly attached to an axis, that it can be surmounted or endured. The conditions of leading the tram road carriage around the curve differ altogether from those of guiding the ordinary road carriage. The tram road carriage will guide itself, with either the Bissel two wheel truck, or, more perfectly still, with the old German six wheeled wagon arrangement, (in which the axles adjust themselves radially to any line of curvature); while the ordinary road carriage must have the swinging axle only for a guide.

In the application of power to the steam carriage, it is apparent that the starting resistance is the most difficult to overcome; and, although many methods suggest themselves, none has yet had practical application in service in parallel work. The utilization of the momentum of stopping *may* be available to help the starting of a carriage. This has already been elucidated as possible on railway trains, but in this case the gain from all the momentum lost at a stoppage bears so small a proportion to the labor of the locomotive engine, as not to be worth saving. The necessity of two speeds, at least, is acknowledged, but with the gearing of the jack-in-the-box, there is no great objection to double speed wheels in addition. The total motive power of the engine demanded is about what is rated two horse power, at the most, and the engine becomes very small. The success of the "three cylinder engine," now made by the thousand, almost, in England, and its peculiar facility for the use of the expansive force of steam, at high velocities, seems to open a ray of light into the darkness where the steam carriage of the future now lays. The recognition of the fact that the interstices of a mass of coal, on a given surface, present an equal area for any size of lump, whether coarse (large) or fine, only that all the lumps or grains must be sorted to the same size, is slowly being made; and as our fine anthracite coal, of *pea* size, runs like water, it follows that automatic firing of

the small boiler will be the finality for the purpose of the steam carriage (as well as the possible finality of the firing of marine, if not all, steam boilers). This, with suitable automatic arrangement for feeding, will permit the steam carriage to be run by one man alone. Only some of the salient points of the mechanism of the coming carriage have been noticed here; others of nearly equal importance present themselves, which can be discussed or settled, in the same way, by those especially interested.

Eventually, the steam carriage will be as distinctive as the locomotive engine, and will have its nationalities as the locomotive has, and its individuality, as the American locomotive of to-day has WM. MASON inscribed upon it.

The steam carriage when in use on the public highways or tram tracks, will be much more safe from accident of any kind than the ordinary vehicle or the street car. The requirement of penalty can be made as stringent as letting all statute laws out of the question will allow the enforcement of common law; and under the impulse of such penalties—safeguards, catchers, detentors or arresters—automatic contrivances of all kinds, will multiply to the point that will give security to the other traffic, quite as great as that now attendant upon the average driver and the carriage horses. While the control of the apparatus, either to start or to stop, *can* be made certainly as effective as the present ordinary carriage, however carefully driven.

The abuse of animals (horses) in our street cars is a shocking evil, and those instincts of humanity which lead us to avoid the occasions or exhibitions of cruelty, now urge with great strength the substitution of inanimate force for so completely mechanical exertion of power. The repairs and restoration of the road ways, consequent upon the employment of horses in so large numbers, form the chief items of expense to the highway department, and the substitution of steam carriages would materially reduce this burden on the city. The removal of the horses from the street railroads alone, would greatly improve the cleanliness of streets, by the prevention of so much decomposable matter now deposited upon the surface of the pavement, to be ground under the wheels to an impalpable powder, blown about with the winds, and vitiate the very air we breathe. With due regard for the public health alone, it is desirable to substitute the steam carriage for the horse car.

The Massachusetts Institute of Technology.—The two papers which appeared in the Feb'y and Mar. numbers of the JOURNAL, viz.: Cotton Spinning, by F. H. Silsbee, and the Use of the Microscope in Qualitative Analysis, by F. W. Very, were theses of advanced students of this institute. An original and fundamental investigation by a competent and studious pupil into any of the common usages of mechanism, will always yield an ample store of unexplored knowledge, and allow the production of a novel and interesting paper, truly valuable to science, and suitable in all ways for publication. It is a great gratification to an editor to be offered papers like those here referred to, which, in place of being the extravagant claims of novelty and performance, are simple descriptions and investigations of actual existing facts. Even when the paper presented, is not the distorted and biased representation of the advertisement of a *scheme*, too often it is merely a study and collation of something found in a book, valueless in repeating all the errors of former collators, and in wanting any truths of original discovery. It is the province of the professor to direct the energies of the student toward such subjects as will allow him to test his book knowledge and apply his natural ability to comprehend and express the technical points which the subject presents. In none of our institutes have the practical branches of applied mechanics been taught with more success, than at the Massachusetts Institute of Technology, and these papers in the JOURNAL can be taken as evidence, not alone of the ability of the scholar, but also of the elevation of the standard of technical education which has been attained at the school. It is for the purpose of giving due credit that this notice is written, as the proper reference to the Institute was omitted in the headings of the papers.

NOTE ON FINDING THE STRENGTH OF A COLUMN OF IRREGULAR SHAPE.

By THOMAS M. CLEEMANN, C. E.

Rankine's general formula for the strength of a column fixed at the ends is:

$$P = \frac{fS}{1 + a\frac{l^2}{r^2}},$$

in which S is the cross section of the column; 1 is the length of the column; r is the "least radius of gyration;" f for wrought iron,

36,000, and for cast iron, 80,000; a for wrought iron, $\frac{1}{36000}$, and for cast iron, $\frac{1}{6400}$.

For columns of ordinary sections, the value of r can be found by the calculus, and its value for many such sections is given in Rankine's "Civil Engineering." It sometimes happens, however, that the cross section may be so irregular or discontinuous, that the calculus cannot be applied. It is then necessary to pursue a different method, and the following one, of obtaining the value of r by experiment, is believed to be new, and is recommended to engineers for its extreme simplicity. It is very similar to that used in Bartlett's "Mechanics," for finding the moment of inertia of a fly-wheel:

Draw the cross-section on stiff cardboard, and cut it out carefully. Make a small hole in any part near the edge, through which insert a pin, and make it oscillate about the pin like a pendulum. Count the number of oscillations in a minute. The length of the equivalent simple pendulum is given by the equation:

$$L = \frac{140796}{N^2},$$

in which N is the number of oscillations performed in a minute. The radius of gyration is then found from the equation:

$$r^2 = \tfrac{1}{2}(L e - e^2),$$

in which e is the distance from the point of suspension to the centre of gravity of the section, expressed in inches. The above is only true when the cross section can be divided symmetrically by two axes at right angles to each other. The sections of columns ordinarily used, however, such as those of the Phœnix Iron Co., and the Keystone and Kellogg Bridge Companies, conform to this condition.

In cases of great irregularity of cross section, the pin should be placed in two or three places near the outer edge, at equal distances from the centre, and the experiment of counting the oscillations repeated. The greatest value of N is the one to be used.

Edson's Time and Pressure Recording Gauge.—One of these instruments was presented and described at the meeting of the Institute in January last, and excited considerable interest.

This instrument, in its present form, consists first of a circular base piece of cast iron, carrying all the other parts. In the upper side of the base piece is a cavity, over which is placed a corrugated diaphragm

spring, about 8 inches in diameter, firmly clamped down at its periphery so as to form a steam tight joint. Into the chamber thus formed, the steam from the boiler is admitted, and raises the spring to a greater or less distance, according to the degree of pressure.

To the upper side of this spring is attached a connecting rod, which, by means of a rockshaft and arms, operates a sliding bar carrying a pencil, which is thus made to move up and down in a vertical line, as the pressure in the chamber increases or diminishes.

By means of clock work, placed in the back of the instrument, a strip of paper is made to move along the front of the instrument at a uniform rate, and in such a position that the point of the pencil shall bear against it. This strip of paper is ruled lengthwise to a scale representing the varying pressures in the boiler, and is ruled crosswise into equal spaces representing the exact space through which the paper will be moved in one hour. These cross rulings are assembled so as to form 24 equal spaces, and numbered and lettered to represent the 24 hours of the day, thus forming charts to be removed and filed away as a permanent record of each day's performance.

It is evident that if this strip of paper should have no movement, and the pressure under the spring should become sufficient to raise it and the pencil, the latter would make a simple vertical mark on the paper, and the only information its after inspection would give, would be the extreme limit to which the pressure had risen.

If, however, while the pencil is thus being moved vertically, the paper is moved horizontally at a regular rate of speed corresponding to one of the crosswise spaces in each hour, an irregular line will be marked on the paper, representing the variation of pressure, and an after inspection will show exactly what the pressure was at any moment during the time it was operating.

Thus a permanent record is made of the pressure in the boiler, which is of value to the owner or manager of any establishment using

steam, enabling him to judge of the faithfulness or ability of the fireman, and detect faults in the safety apparatus, and may also be of much benefit to the honest fireman, by pointing out errors he may have committed in the management of his fires.

On the front of the instrument is an index hand, which, by means of the proper mechanism, is moved over a segmental scale, graduated to show the pressure in the boiler at any time by inspection, as in the ordinary gauge.

The rockshaft, before mentioned, carries an arm, which can be so adjusted as to close the circuit of an electric alarm bell when the pressure shall reach the prescribed limit.

The use of this instrument is not open to the objection often urged against automatic attachments to boilers, which are designed to do by machinery that which should be done by the attendant, as this is in no wise intended to assist him or relieve him of his present duties, but simply makes an exact record by which others may know when, and to what extent, fluctuations of pressure have taken place in the past. K.

The Storage of Petroleum, Benzine, or Similar Fluids, while on Draught for Use or Sale.—The class of substances here mentioned have now become articles of common and necessary use in manufactories, and regular branches of traffic in the shops: and many accidents, with sometimes serious disaster, result from their unexpected ignition and explosion. The great danger, of course, lies in the explosive mixture of air and hydro-carbon vapor, which forms in the partially empty tanks, barrels, or containing vessels, which occasionally ignites, notwithstanding the great care that may have been exercised to prevent any access of flame to the mixture. Wherever these fluids are kept it is usual to establish strict rules about drawing them off at night, and against the proximity of any light at any time. But when it is considered that a current or stream of the mixed vapor and air will convey a spark more rapidly than a train of gunpowder, it is not to be wondered at, that every few days add to the record of coal oil explosions. Having become cognizant of the repeated explosions of a benzine storage tank at a gas-works—from flame twenty-five feet away—from a laborer's pipe entering the shed, from a plumber's furnace at a long distance; the writer advised the adoption of a plan which would effectually prevent all future accidents of this nature.

As the same plan is applicable to all tanks or vessels for storage of these fluids, the present publication is made to bring it into notice. In the case of the gas works, all that was necessary to be done, was to close the top of the tank gas-tight, and connect a pipe from the top to the gas mains.

Where the tank is to be supplied or re-filled by means of a pump, it is only needful to connect the supply pipe to it by a tight joint, but if the oil or benzine is poured in, a syphoned or sealed mouth or tube must be attached to the tank so that it can be filled, with, of course, the extra resistances of (in this case 3 inches of water pressure), and equally, of course, upon drawing out any benzine, it would be discharged under (3 inches) greater head than the height of benzine above the faucet. The result of the arrangement was to fill the space above the benzine with common gas, which may be inflammable enough to burn in air, but which is wholly inexplosive. In manufactories or shops which are lighted by gas, the same arrangement is feasible, and it is only necessary to connect the top of the closed oil or benzine to the gas pipes of the building. Where dry meters are used for measuring the supply of gas, they will register backwards the few feet of gas displaced by a fresh supply of oil or benzine, and most wet meters will also act in the same way. For some constructions of wet meters it would be best to lead a discharge gas pipe from top of this tank, and waste the contents of gas, when a fresh supply of benzine is received. Another method is to attach the faucet to the top of the tank, or barrel, and connect the water pipe to the bottom, thus putting the contents of the barrel under the pressure of the water service, and preventing any influx of air, and precluding the existence of any vapor above the oil or benzine. And this arrangement can be modified by a separate vessel of water, in place of the water service of the city or town. For general convenience of application, and especially upon a large scale, where several barrels are to be stored, the gas connection is the most available, and the adoption of this method of preventing accident by manufactories and shops would be a real protection for property and life.

The storing of benzine under an *atmosphere* of gas, is open to an objection arising from the absorption of a small quantity of gas by the benzine itself. The only real trouble which will follow, will be the emission, for a short time, of a gaseous odor when the benzine is used; so far as the gas itself is concerned, it will be much improved in its illuminating powers by the absorption of a small proportion of vapor of benzine. B.

Franklin Institute.

HALL OF THE INSTITUTE, March 15, 1876.

The stated meeting was called to order at 8 o'clock, P. M., the President, Dr. R. E. Rogers, in the chair.

There were present 165 members and 28 visitors.

The minutes of the last stated meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting the following donations were made to the library

Catalogue of U. S. Coast Survey Charts. Washington, 1875.

Report of the Superintendent of the U. S. Coast Survey, showing the progress of the survey during the year 1854. Washington, 1855; and during the year 1872. Washington, 1875.

On the Use of the Zenith Telescope for observations of time, by J. E. Hilgard.

On the Reclamation of Tide Lands, and its relation to navigation, by Henry Mitchell.

Treatise on the Plane Table and its use in Topographical Surveying.

Memoranda relating to the field work of the secondary triangulation, prepared by R. D. Cutts, assistant.

On the Air contained in Sea Water, by Oscar J. Jacobson.

Appendices Nos. 9 and 13 of Coast Survey Report for 1867.

Appendices Nos. 19 and 21 of Coast Survey Report for 1870.

Appendices Nos. 8, 16 and 17 of Coast Survey Report for 1871.

Appendices Nos. 12 and 14 of Coast Survey Report for 1873.

Report on Mt. St. Elias by W.H. Dull, acting assistant, U. S. C. S.

Discussion of Tides in New York Harbor, by Wm. Ferrel. From J. E. Hilgard, assistant in charge of office U. S. Coast Survey, Washington, D. C.

One year's subscription to War Dept. Weather Map, issued daily from Washington, with a file for the same. From L. T. Young, Philadelphia.

Bulletins 5 and 6 of the U. S. Geological and Geographical Survey of the Territories. Sec. Ser., Washington, January 8th, and February 6th, 1876.

Bulletins 1 and 2 of the U. S. National Museum. No 1, Check List of North American Batrachia and Reptila, by E. D. Cope.

No. 2, Contributions to the Natural History of Kerguelen Island, by J. H. Kidder, M.D. Washington, D. C., 1875. From the Dept. of Interior.

Report of the Meteorological Reporter to the Government of Bengal. Meteorological abstracts for the years 1867–'74. Calcutta.

Administration Report of the Meteorological Reporter to the Government of Bengal, for the years 1870–1875.

Report of the Midnapore and Burdwan Cyclone of the 15th and 16th of October, 1874, by W. G. Wilson, M. A. Calcutta, 1875. From Henry F. Blanford. Calcutta.

Specifications and Drawings of U. S. Patents for August, 1875. From the Commissioner.

Astronomical and Meteorological Observations made during the year 1873, at the U. S. Naval Observatory. Rear Admiral B. F. Sands, U. S. N. Supt. Washington, 1875. From the Supt.

Pennsylvania Archives Sec. Ser. Published under direction of M. S. Quay, Secretary of the Commonwealth. Vol. 3. Harrisburg, 1875. From the Secretary.

Constitution and By-Laws of the Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, with the Act of Incorporation. Philadelphia, 1844.

Official Catalogue of the New York Exhibition of the Industry of all Nations. Revised edition, 1853.

Transactions of the Geological Society of Pennsylvania, August, 1834. Vol. 1, Part 1.

An Essay on Chemical Analysis, chiefly translated from the fourth volume of the last edition of the Traité de Chimie Elementaire of L. J. Thenard by J. G. Children. London, 1819. From Geo. W. Hall.

Twenty-fourth Annual Report of the Board of Water Commissioners to the Common Council of the City of Detroit, together with the Reports of the Officers of the Board for the year 1875. Detroit, 1876.

Die Congerien und Paludimenschichten slavoniens und deren faunen. Ein beitrag zur descendenz-theorie von Dr. M. Neumayr und C. M. Paul, 1875.

Das Gebirge und Hallstatt, eine geologisch-Palaontologische studie aus dem Alpen von Edmund Mojsisovics v. Mojswar, 1875. From the K. K. Geologishen Reichsanstalt. Wien Oestereich.

Transactions of the Royal Irish Academy. Vol. 24, Parts 9, 16 and 17. Vol. 25, Parts 1–20, inclusive. From the Academy. Dublin.

Aeneidea, or critical, exegetical and aesthetical remarks on the Aeneis, by James Henry. Vol. 1. Ireland, 1873. From the author.

Experiments with the alleged new force, by Geo. M. Beard, A.M., M.D. New York, 1876. From the author.

Memoire sur les occulations d'etoiles par les planets par J. A. Normand. Paris, 1876. From the author.

Eighth Annual Report of the Pennsylvania Society for the Prevention of Cruelty to Animals. Philadelphia, 1876. From the Society.

A paper by Mr. Jno. E. Wooten, of Reading, Pa., on "A combination of apparatus by which ordinary anthracite coal waste from the dust banks at the mines is successfully burned in stationary and locomotive boiler," was read by Dr. C. M. Cresson.

Some discussion followed, which was participated in by Drs. Koenig and Cresson, and Mr. Orr.

The Secretary presented his report, embracing L. T. Pyott's Hoisting Machine; D. M. Pfautz's Flying Draw Bridge; Walter Hart's Adjustable and Removable Flag and Banner Bracket; an impact Brick Machine, the invention of McLean & Bennor; a rapid and economical method of engraving, invented by M. Joyce, Washington, D. C.

Also an illustrated description of the subterranean wall being constructed for the preservation of the Falls of St. Anthony, Minn., with a letter from Maj. F. U. Farquhar, U. S. A., giving the progress of the work to February 21st, last.

Mr. Gray, who had been invited to exhibit and explain his system of Electro-Harmonic Telegraphy, was then introduced, and gave a large number of experiments illustrating the working of his system.

At the request of Mr. Robert Briggs, his description of Prof. Crook's Radiometer was postponed on account of the lateness of the hour.

A letter from Mr. B. H. Moore was read, acknowledging the receipt of the resolution passed at the last meeting in relation to his resignation as Vice-President, tendered at the last meeting, and repeating his request that it may be accepted, giving as reasons his impaired health and great press of private business.

On motion, the resignation of Mr. B. H. Moore as Vice-President was accepted.

On motion, the election of a Vice-President to fill the vacancy caused by the resignation of Mr. Moore, was postponed to the next monthly meeting.

The following gentlemen were placed in nomination for Vice-President: Mr. H. G. Morris and Dr. C. M. Cresson.

On motion, the nominations were kept open until the next meeting.

At the suggestion of Mr. Coleman Sellers, who was unable to be present at this meeting, the Secretary offered the following resolution, which was unanimously adopted.

Resolved, That the Secretary of the Franklin Institute be directed to invite the American Railway Master Mechanics to the Institute during their session in May, and that the Hall of the Institute be placed at their disposal for their meetings, if it can be arranged so as not to interfere with any of the uses or engagements of the Institute.

On motion, the meeting then adjourned.

J. B. KNIGHT, *Secretary.*

Preservation of the Falls of St. Anthony.—At the last meeting of the Institute the secretary gave an illustrated description of the work being executed by the U. S. Government, for the preservation of the Falls of St. Anthony, and read the following from Major F. U. Farquhar, under date of Feb. 21st, 1876,in relation to the progress of the work.

"Since the writing of my report for 1875, we have finished that part of the work under the east branch of the river, except the filling up of the passages, these being now about half filled.

"Under the main river the excavations and dyke have been carried to a distance of 1100 feet from the shaft, on Hennipin Island, or to within 200 feet of the end of the work in that direction.

"Just at the angle where the wall turns to go across the river, we encountered a stream of water, which brought into the excavation and passages a quantity of sand so great as take nearly three weeks to remove it. Except this, we have had no great drawback.

"The work being underground, we work during the winter, day and night, and but for a lack of funds, the dyke would have been finished by April 1st."

The St. Gothard Tunnel.—The St. Gothard Railway Company have just published their monthly statement of the progress of the works of the St. Gothard Tunnel during the month of December. The position of these works at the 31st of December, 1875, was as follows:—Total length driven, 5409·80 meters; length remaining to be driven, 9510·20 meters; total length of tunnel, 14,920 meters. The

following statement shows the monthly progress made during December, and the position of the different kinds of work at the end of 1875:

Description of works.	North side. Goeschenen.			South side. Airolo.			Total length at 31st December.
	Length driven at 30th Nov.	Length driven in December.	Total length at 31st December.	Length driven at 30th Nov.	Length driven in December.	Total length at 31st December.	
Leading heading	2771·5	39·3	2810·8	2509·0	90·0	2599·0	5409·80
Enlargement of roof	1372·8	188·0	1480 8	1074·0	78·0	1152·0	2632·80
Following tunnel or cuvette	1315·1	63·8	1378·9	790·0	51·0	841·0	2219·90
Enlargement of " "	603·6	90·2	693·8	479 0	51·0	530·0	1223·80
Completed tunnel	88·0	.	88·0	145 0	—	145·0	233·80
Masonry, arch	692·0	40 8	732·8	825 36	4·64	830·0	1562·80
" east side wall	400·0	69 0	469·0	101·9	—	101·9	570·90
" west " "	414·5	44·5	459·0	690·6	39·1	730·0	1189·00
" invert	—	—	—	—	—	—	—
Diameter	—	—	—	126·0	—	126·0	126·00

The Theory of the Height of Chimneys.—It will be noticed that the paper on "Steam Boilers and Chimneys," which appears upon other pages of this JOURNAL, passes over the steps of computation of the effect of temperature of the column of heated air on the draft—only giving the results. It is intended to recur to this subject again, at an early day, possibly in the May number ensuing, and then to exhibit more fully the anomaly of a maximum of induced velocity, at the temperature of 623·4° Fahr., and at the same time to *consider* the effect of the extra height of the column of heated air above the chimney, and endeavor to bring *it* into correspondence with the actual height of the chimney itself. The method of overlooking all specific resistances, and accepting a performance of a standard chimney as a basis, adopted in the article is, it is thought, new; and the results, as exhibited in the final table of the paper, are possibly less open to criticism than some which have been published. But the writer has frequently found, at the base of a chimney, an indication of water column, incompatible, in its great value, with the theoretical draft at *supposed* or *supposable* temperatures; and after the paper in question had gone to press, he was led to think that the effect of the ultra column of heated air in the atmosphere, would account for the discrepancy apparent in these cases; and also for the great efficiency of short chimneys at high temperature; as, for instance, those of marine boilers.

Railway Improvement and Extension in Great Britain. The half year ending December 31st, 1875, was marked by the unprecedented large return of traffic on the railways, exhibiting the flourishing condition of the business of the nation during the time; and the conclusion of the usual half yearly meetings of the companies permits the *Builder*, of March 18th, to publish a general statement at some length, which gives amongst other particulars the proposed expenditures of the leading companies for the current half year on new work. The total stated for eight companies is over twenty-two millions of dollars in currency, (at present rates), as the *authorized* current expenditures for improvements and extensions for the six months ending June 30, 1876.

Absorption of Hydrogen by Iron.—From the *Engineer*, Jan. 28th, 1876.—The well known French chemist, M. Gailletet, has continued his researches into the absorption of hydrogen by iron, with some interesting results. It appears that when an iron plate is attacked by sulphuric acid being poured over it, a portion of the hydrogen produced is absorbed by the metal, and the pressure of the gas which is accumulated between two iron plates, welded together, is sufficient to counterbalance a column of mercury 13¾in. high. This singular property of hydrogen, which has also been confirmed, lately, by the investigations of M. Sevox, is regarded by the latter as a most interesting discovery, and he attributes to the presence of carbonic oxide or hydrogenized gas, the brittleness which some classes of iron manifest when an attempt is made to draw them into wire, a fact well known to workers in this metal. It is also found that, when decomposing, by the galvanic battery, a solution of chlorate of iron to which sal-ammoniac has been added, metallic iron may be collected at the south pole in a form of a brillant wart, brittle and often hard enough to scratch glass. This iron after being washed, evolves, either under water or another liquid, numerous bubbles of gas, which is pure hydrogen. When freely exposed to the air, galvanic iron loses only a portion of its hydrogen; under water, especially water heated to 140 or 150 deg., the hydrogen is given off with violence. As to the quantity of hydrogen iron thus treated can take up, it seems that, for one volume of iron, the amount is two hundred volumes of gas; in weight thirteen parts of iron absorb one part of gas. When a lighted match is applied to this iron, saturated with hydrogen, the gas burns like alcohol

Breakage of Submarine Telegraph Cables.—Sir William Thomson and Mr. F. J. Bramwell, to whom was intrusted the examination of the broken ends and the recovered section of the recent fractures of the direct United States Co.'s cable, have made their report.

There were two fractures, one on Sept. 27th, 1875, in 70 fathoms, and the other on Dec. 10th, 1875, in 120 fathoms.

They found the ends of the wire, of which the cable is composed, tapered down, as is always the case in good ductile metal. There was no evidence of decay or of an imperfect condition of the cable, nor of the cable chafing against the rock or crushing; and they can come to no conclusion but that the fracture occurred in a perfect cable, though thoroughly sound metal, and that they were due to that metal having been torn asunder, under violent tensile strain.

They further say, in regard to the first fracture, that this violent strain must have been caused by an implement, such as the arm of a grapnel or the fluke of an anchor, which, after coming in contact with the cable, was run along, driving the serving into the hemp, until there was formed a thick mass around the cable for a length of 13 inches. This mass finally stopped the progress of the implement, as is shown by its marks on the serving, and the breaking strain then commenced.

About 12 knots of the cable were recovered, and this was subjected to examination and test, and was found to be in excellent condition and free from fault. It was also submitted to test of breaking strain, and its power to resist tensile strain was placed at 7 tons.

This report offers no satisfactory explanation of how such a strain came to be applied, but concludes that it could not have been accidentally produced by fishing vessels in pursuit of their ordinary calling.

The steamer Faraday has also succeeded in picking up the fractured ends of the New Hampshire-Torbay cable, broken on Jan. 23d, 1876, at a depth of nearly 100 fathoms, and the representatives of the company state that the fracture presents the strongest evidence of having been produced by cutting with an axe or hatchet, after having been raised by an anchor; but whether this was done from malice, or in self-defense by a vessel under stress of weather, remains to be proven. In any view of the subject, there seems to be a necessity of some international law regulating the actions and responsibility of vessels in such cases, and to settle the question of jurisdiction in matters relating to submarine cables. K.

Civil and Mechanical Engineering.

GRAPHICAL AND ANALYTICAL DETERMINATION OF STRAINS IN A ROOF TRUSS

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The present article is written in compliance with a request made to the author, to present in as popular a manner as possible the different methods of finding the strains in the various pieces of a roof truss of frequent occurrence in practice. The example here worked out accompanied the above request, and although perhaps not exactly calculated to show to the best advantage the peculiar merits of a graphical solution, will, we trust, be sufficient to enable the reader unacquainted with the method, to extend it to other and more irregular forms of trusses.

We shall first find the strains in the various pieces of the frame, due to dead load, by diagram; then indicate the methods of calculation, thus checking the results of diagram; and finally find the strains due to *wind force*, for which roof trusses are too rarely investigated, and for the determination of which the graphic method is peculiarly suited.

I. Outer Forces.—The truss proposed for solution is represented in Fig. 1. The span is 50 ft.; height of truss 12·5 ft.; diagonal bracing as shown in the Fig.; bottom tie horizontal without camber. The skeleton of the truss, drawn carefully to scale according to the given dimensions, we call the *frame diagram*. We have given it in Fig. 1, to a scale of 12 ft. to an inch for convenience of publication merely. In the actual determination of the strains which we shall give, it was drawn to a scale of 5 ft. to an inch. Now the *frame* diagram being thus carefully drawn to a suitable scale (in general the larger the better), we have first to determine the *outer forces* which

act upon the truss. In the example proposed each truss similar to Fig. 1, supported 5 ft. in length of roofing, and the total weight of this section of 5 ft., including slate, truss, roofing, etc., was 15 lbs. per sq. ft. Snow was taken at 5 lbs. per sq. ft. We have then for the length of each rafter, $\sqrt{25^2+12\cdot5^2}=\sqrt{625+156\cdot25}=\sqrt{781\cdot25}$ $=27\cdot95$ ft. or 28 ft. The total area of roof, therefore, for each section of 5 ft. will be $28\times5\times2=280$ sq. ft. At 15 lbs per sq. ft. this will give 4200 lbs. For snow, we have in addition $280\times5=1400$. Hence, total maximum load including snow, is $4200+1400=5600$ lbs. Now this load we may consider as divided into a series of loads at each apex; *omitting the two ends*, at which strictly we have 400 lbs. apiece. The strain in the rafter is in reality cumulative, increasing towards the ends. By the above method we find this maximum strain at the end correctly, and then consider the cross-section uniform to next apex, thus getting somewhat more than the area necessary. At each of the seven apices, then, omitting the ends, we have a vertical weight of 800 lbs., as represented in Fig. 1 by the vertical arrows. At the ends we have a vertical upward reaction of half the total weight, or 2800 lbs. Thus all the *outer forces* which act upon the truss are known, and it remains to find the strains caused by these forces in the various pieces. This we shall do in two ways—1st, by diagram; 2d, by calculation.

I. GRAPHIC SOLUTION.

II. NOTATION.—Let us first explain the notation which we have adopted for Fig. 1. Let all the space above the truss be denoted by the letter A, and all below it by the letter B, and then number the spaces within the truss by 1, 2, 3, 4, 5, 6, etc. Then the four pieces composing the rafter are A 1, A 2, A 4 and A 6; the three divisions of the tie are B 1, B 3, B 5, while the braces are 1 2, 2 3, 3 4, 4 5, 5 6, and 6 6′, respectively; corresponding spaces in the right half being denoted by primes. The great convenience of this system of notation will soon appear. [For the above elegant system of notation we are indebted to *R. H. Bow's* "*Economics of Construction*," where the reader will find the following method of graphic solution very clearly set forth, and illustrated by numerous examples.] The preceding system of notation being understood, we can now proceed to the principles of which we shall make use, in the solution of the problem before us.

III. General Principles.—The principles of which we make use in this and all similar problems, are very simple and familiar to all. They are indeed among the most elementary in mechanics. The problem proposed is essentially a *statical* problem. That is the end to be obtained is rest or *equilibrium*. Thus at each apex, as we have seen, we have an outer force acting. The tendency of this force is, of course, to cause motion of the material point upon which it acts. But the force at each apex causes strains in the pieces which meet at that apex, and these strains must be so great and must act in such direction, that they exactly oppose and neutralize the action of the outer force. That is, *at each apex the strains in all the pieces which meet at that apex, are in equilibrium with the outer force which acts upon that apex.*

Now the principles of which we make use, and which here directly apply, are as follows:

1st. *If any number of forces, all in the same plane, are in equilibrium, the polygon formed by drawing lines parallel to the directions of these forces, and equal by scale to their intensities, must close.*

It will be seen at once, that, according to this principle, if we have only three forces acting upon a point and holding that point in equilibrium, and if *one* of these forces is known; then, if we draw a line parallel to the known force, and make it equal by scale to the known intensity of that force, the other two forces can be easily and directly determined *to the same scale*, by lines respectively parallel, which are prolonged till they intersect and thus close the polygon, which in this case is a triangle. Generally, no matter how many forces act upon the point in question, if they are in equilibrium, and if we know all but two of them, we have only to lay off to scale the known forces in the proper directions, and then "close" the polygon thus commenced by lines parallel to the known directions of the two unknown forces. We thus find to scale the intensities of these forces necessary and sufficient for equilibrium. If more than two forces are unknown, the problem is in general indeterminate.

Corresponding to this method of diagram, we have a method of *calculation*, which consists simply in solving trigonometrically the triangles and polygons thus obtained.

2d. *If any number of forces acting upon a point are in equilibrium, and if we take any point in the common plane of the forces as a centre of moments, then the tendency to rotation about this point is*

zero, or the sum of the moments of all the forces tending to cause rotation in one direction is exactly equal and opposite to that tending to cause rotation in the opposite direction.

The principle is self evident if there is to be equilibrium or no motion, and upon it we may base a perfectly general method both of diagram and calculation. It will thus be seen, that by these two principles we have *four* different and distinct methods of solution; two by diagram and two by calculation. The first method of diagram which we shall here make use of, is known very generally as *Prof. Clerk Maxwell's* method, the corresponding method of calculation may be called the method by "composition and resolution of forces."

The second principle gives rise to a method of calculation which is simple, easily acquired and applied, and perfectly general, provided all the *outer forces* are known. This method we may call the *method of moments* or "Ritter's method." Prof. August Ritter in his work entitled *Dach und Brüchen Constructionen*, has shown so exhaustively the generality of the method, and applied it in such detail to so many forms of construction, that although the principle is itself as "old as the hills" it well deserves to be thus known by his name.

Now, corresponding to this general method of moments, we have a *method of diagram* equally general, which lies properly at the basis of the new science of "Graphical Statics," and which, for similar reasons, we may call "*Culmann's method*"—in compliment to the man who, more than any other, has done most for its perfection and elucidation. This second method of diagram we shall not touch upon here, but refer the reader for an exposition of *all* these methods, together with their dependent principles, illustrated by numerous examples, to the author's work upon the "*Elements of Graphical Statics*," etc.; John Wiley & Son. We shall, however, in what follows, make use of the first method of diagram above, as also of its correlative method of calculation, and shall also notice briefly the method of calculation by moments, which rests upon the second principle above enunciated. Although we shall here illustrate these principles by a single concrete example, the reader will, we trust, find no difficulty in applying them to *any* example which can occur in practice. Even in bridges, if he will thus find the strains in every piece due to each *separate* apex load considered by itself, and then form a table showing the strains thus found for each load, he can easily and unerringly pick out the maximum strain which, under any possible combination of

loads, can occur in any given piece. [For an exposition of this method, see also the work of the author above cited.] Thus for every framed structure, of whatever kind, we have a simple and general method, and the real solution of the problem in any case is in reality confined to finding the *outer forces* which act upon the structure. These in roof trusses, simple bridge girders, etc., are easily found. The weights are always known, the reactions at the ends easily found by the "law of the lever." For continuous girders or girders continuous over more than two supports, for braced arches, etc., these outer forces, more especially the "reactions," are not so easily found. Once known, the solution is easy. The whole problem of solution of framed structures is thus reduced to finding the *outer forces*. In all ordinary engineering structures these are easily found, and hence, no difficulty is experienced. For those structures of less frequent occurrence, already noticed, the determination of the outer forces for *each separate apex load considered by itself*, is by no means so difficult as has generally been supposed. This, as we have seen, is, however, all that we need; and for such methods of determination, we refer again to the above work of the author.

IV. APPLICATION OF THE ABOVE GENERAL PRINCIPLES.—Let us now proceed to apply the general principles of Art. III, to the case in hand. We take up, therefore,

1*st. Maxwell's Method of Diagram.*—In Fig. 1, we have acting at the toe of the rafter, an upward reaction of 2800 lbs. This upward reaction causes strains in the pieces A 1 and B 1 (see Art. II for notation). According to our first principle then (Art. III), the strains in A 1 and B 1 must, with the reaction of 2800 lbs., form a system in equilibrium; and hence, the polygon formed by parallel lines must *close*. This polygon we call the *strain polygon*. Thus in Fig. 2, we lay off the distance A B, equal to 2800 lbs., by scale. In the figure we have taken 3200 lbs. to an inch. In the actual example we took 800 lbs. per inch, but have reduced the original diagram, for convenience of size. A B, then, is by scale 2800 lbs. We draw, then, A 1 in Fig. 2 parallel to A 1 in Fig. 1, and B 1 parallel to B 1, and produce these lines to intersection 1. The polygon is then closed, and A 1 and B 1 measured off to scale, will give at once the strains in the corresponding pieces.

We have now to call attention to a *very* important point. We have thus far the intensity of the strains in A 1 and B 1, but have yet to

find whether these strains are compressive or tensile. For this we have the following rule:

Follow round the strain polygon, in the direction of the known forces. We thus obtain certain directions for the unknown forces. Refer these directions to the apex at which the forces considered are supposed to act; a direction away from this apex is tension—towards, compression.

Thus, in the above case, we *know* that A B acts up. We follow round then, with this to guide us, from B to A; and then continuing round from A to 1, and 1 to B again. Now, looking back to the frame, we find A 1 acting towards the foot of rafter, which is the apex now considered, therefore compression; while 1 B acts away, therefore tension. The amount of compression or tension is indicated by the length to scale of the corresponding lines.

Now, having found A 1 a certain number of pounds compression, as shown in Fig. 2, we can find 1 2 and A 2; because at the apex, where these forces meet, we know two forces acting there, viz.: A 1 already found, and A A = 800 pounds given, and there are only two others unknown, viz.: 1 2 and A 2. A 1 and A A are shown in Fig. 2, already drawn to scale. A 2 and 1 2 closing the polygon commenced by these two forces, give at once to the same scale the strains in the corresponding pieces. Again as to the *quality* of the strains, observe that A A the weight, acts *down*. We pass round then, with this to help us, from A to 2 and 2 to 1, and so around. Then referring to the apex *at which all these forces act*, we have A 2 towards, therefore compression, and 1 2 ditto, and if we should still go round, A 1 also towards the new apex, or compression, as before found, thus checking our previous result.

Now we can pass to the first apex on the lower tie, because we know already B 1 and 1 2, and have only to find two unknown strains, 2 3 and B 3. We draw then in Fig. 2, 2 3 to intersection with B 1. We have then B 1, 1 2, 2 3 and B 3, closing the polygon. B 1 has already been found to be tension. With reference to the apex we are *now* considering, therefore, it acts *away;* we follow round then from B to 1, then 1 to 2, and then 2 to 3 and 3 to B again, and thus find by reference to the frame, 1 2 compression as already found, 2 3 tension, and 3 B tension. Now knowing A 2, 2 3, and the weight 800 pounds = A A, we can find A 4 and 3 4 as before, both compression. So we pass through the frame. Next time with B 3 and 3 4 known, we

find 4 5 and B 5; then with A 4, 4 5 and the weight A A all known, find A 5 and 5 6. Now knowing A 6 and the weight A A = 800 pounds at summit, we find A 6′ and 6 6′, the one compression, the other tension. Observe that as we proceed, now finding the strains in the right hand half of the truss, we *check* each time our previous results. The diagram thus checks its own accuracy. The points 6 and 6′, 4 and 4′, 2 and 2′, are vertically over each other. If at any point we have committed an error, we can thus detect and remedy it. Observe, also, that while all the seven weights A A = 800 pounds, act downwards, the two reactions A B and B A act upwards, and just come back to the point of beginning, thus closing the "polygon," which in this case is a straight line, in accordance with our first principle, Art. III. In the case of wind force, or inclined reactions, this polygon is a true polygon instead of a straight line, as we shall see hereafter. This polygon we call the *force polygon*. We have thus the *frame diagram*, the *strain diagram*, and the *force polygon*. In every case, since the reactions are called forth by the outer forces, this latter must close. Unless it does close, we have not found the outer forces correctly, and cannot proceed to form the strain diagram. The strain diagram being completed as above, and checking its own accuracy, we can scale off with the dividers the strains in every piece. Representing compression by + and tension by — we thus find, for the lower flanges: B 1 = — 5624, B 3 = — 4832, B 5 = — 4024; for the upper flanges: A 1 = + 6280, A 2 = + 5816, A 4 = + 4712, A 6 = + 3584, and for the diagonals: 1 2 = + 720, 2 3 = — 720, 3 4 = + 1048, 4 5 = — 928, 5 6 = + 1472, 6 6′ = — 2410. As the liability to error of the author working rapidly does not exceed $\frac{3}{100}$ths of an inch, these strains may be depended upon within 2 4 or 2 5 pounds. In the Fig. 2, compression is represented by heavy lines. The checking of both halves of Fig. 2 gives us assurance of the correctness of our results.

2*d. Corresponding Method of Calculation.*—We can still check our results by calculation. We have only to solve trigonometrically the triangles of Fig. 2. This from the known weights, reactions and proportions of the frame, we can easily do. The *quality* of the strains, whether tension or compression, is easily determined as before. Thus, Fig. 2 comprises a set of *rules*, by which we may calculate the strains directly, without tedious and elaborate reasoning as to the way in which strains are "resolved," etc.

For instance, from Fig. 2, we see at once that A B × sec B A 1 = strain in A 1, and A B × tan B A 1 = strain in B 1. Now sec. B A 1 = $\frac{27{\cdot}95}{12{\cdot}5}$ and A B = 2800, therefore str. in A 1 = $2800 \times \frac{27{\cdot}95}{12{\cdot}5}$ = 6260, against 6280 as found by diagram. Again, tan B A 1 = $\frac{25}{12.5} = 2$, hence strain in B 1 = 2800 × 2 = 5600 lbs., against 5624 as found by diagram. Again, directly from Fig. 2, we have, strain in 12 = (A A × cos A 1 B) × sec. of the angle which 1 2 makes with the perpendicular to A 1. For the secant of this angle we easily find 1·008. Now, A A = 800 and cos A 1 B = $\frac{25}{27{\cdot}95}$ hence strain in 1 2 = $\left(\frac{25}{27{\cdot}95} \times 800\right)$ 1·008 = 721 lbs., against 720 found by diagram.

Again from the Fig. A 1 — A A sin A 1 B — [A A cos A 1 B × tan of angle of 1 2 with perp. to A 1] = A 2. But A 1 we have already found 6260, A A = 800, sin A 1 B = $\frac{12{\cdot}5}{27{\cdot}95}$ cos A 1 B = $\frac{25}{27{\cdot}95}$ and for the tan. above, 0·126, hence A 2 = 6260 — 357·8 — 90·1 = 5812 lbs., against 5816 as found by diagram. So we can go through the whole system of triangulation shown in Fig. 2 and check our results. It is advisable to use logarithms, instead of natural sines, etc., as above.

The above methods are of course perfectly general and apply to *any* form of roof truss. In the case, however, of a curved roof truss, the method of diagram is always equally simple and ready of application, while the corresponding method of calculation is often tedious and involves much intricate trigonometrical computation. In fact, just here is the great advantage of the graphic method, that while perfectly general, it is unaffected by the irregularity of the frame. One case is no more difficult than another.

3*d*. *Method of Calculation by Moments.*—We have still to consider the method of calculation based upon our 2d principle, Art. III. For the method of diagram corresponding to it, we must refer to our work upon "*Graphical Statics*," already quoted, as its development would far exceed the limits of the present article. We may only remark here that upon it has been founded an entire system of statics, not less elegant and far more general than the above method of dia-

gram. Thus it will be observed that the method of diagram already noticed, applies only to *framed* structures or structures in which the strains must follow certain *definite directions;* the latter method, on the contrary, applies as well to solid structures also. For the application of the first method all the outer forces must first be known; by the second, these forces may themselves be found. Though some few of the principles of this method have long been known and applied, notably by *Mery* (*Ann. d. ponts et chauss.*, 1840, *sem.* 1 *p.* 50) to the stone arch, yet its thorough development and the deduction of a regular system applicable to all statical problems, of which the arch is but one of many diverse problems, is due entirely to *Culmann*, ("*Die Graphische Statik*," 1866), and by his name it may well be called. The corresponding method of *calculation* owes, as already stated, much of its development to *Ritter*,* and to that we shall now proceed.

Thus, according to our 2d principle, Art. III, if we suppose a section made entirely through the truss, cutting all the pieces which it meets, then for equilibrium the algebraic sum of the moments of the strains in these pieces with reference to any point, must be balanced by the algebraic sum of the moments of all the outer forces acting upon the section of the truss right or left of the points of division, with reference to this same point. Now we know all the outer forces. Since our centre of moments may be *anywhere* in the plane, we have only to assume it *at the common point of intersection of all the cut pieces except one.* The moments of the strains in these pieces will then be zero, and we have only the moment of one unknown strain balanced by known moments. If now we know the lever arm of this unknown strain, it is itself easily found. Thus suppose in Fig. 1, we were to take a section cutting the pieces A 2, 2 3 and B 3. If we take the centre of moments at the common intersection of 2 3 and B 3, the moments of the strains in these pieces with reference to this point will be zero. Considering then the left hand section, we have the moment of the reaction acting up and causing, therefore, compression in A 2, *minus* the moment of the first apex weight, balanced by the moment of the strain in A 2. The lever arm for A 2 we easily find to be 3·72 ft. Hence strain in $A\,2 \times 3{\cdot}72 = 2800 \times 8{\cdot}333 - 800 \times 2{\cdot}08 =$

* In the author's work upon Graphical Statics the method is further applied to the continuous girder, draw-span, braced iron and stone arch, etc., and shown to be of universal application.

21669·333 hence strain in A 2 $= \frac{21669 \cdot 333}{3 \cdot 72} = +$ 5855, against 5816 as found by diagram.

Again suppose A 1 cut, we have the same lever arm as before, *i. e.* 3·72, but no apex weight left of the section, hence simply A 1 $\times$ 3·72 $=$ 2800 $\times$ 8·33 or A 1 $= \frac{23333 \cdot 333}{3 \cdot 72} =$ 6272 against 6280 as found by diagram.

Again, cutting B 1 and taking the point of moments at intersection of 1 2 and A 1, we have B 1 $\times$ 3·12 $= -$ 2800 $\times$ 6·25, or B 1 $= \frac{17500}{3 \cdot 12} = -$ 5607, against 5624 as found by diagram.

So we proceed, cutting each flange and taking the apex opposite to that flange as a point of moments, and taking the moments of all the forces left of the cut flange, with proper signs, and equating to the moment of the strain in the cut flange. The method for the diagonals is precisely similar. Here the intersection of the other pieces is at the end of the truss, which may then be taken as a common point of moments for all the diagonals. In any case, the main and only difficulty is the determination of the various lever arms; for a curved roof truss this involves much calculation. Such calculations, though sometimes long, are, however, always simple, and the lever arms may even be measured off to scale from the frame diagram with sufficient accuracy.

We have thus, as we see, two independent methods of calculation, and one (properly two) method of diagram, either of which are simple and perfectly general. Of the methods of calculation, the last is to be preferred as the simplest, and easiest of application. The method of diagram will, in most cases, be found preferable to all. Especially is this the case when we consider *wind force*, to the discussion of which we shall now proceed.

II. WIND FORCE.

V. It is of considerable importance to investigate the influence of a partial load, such as that caused by the wind blowing upon one side of the roof, and this, by the aid of our graphic method, we can easily do.

If P is the intensity of the wind pressure in pounds per square foot upon a surface perpendicular to its direction; i, the inclination

of any plane surface to this direction; P_n the normal pressure, P_h the horizontal component of this normal pressure, and P_v its vertical component; then we have

$$P_n = P \sin i^{1.84 \cos i - 1}.$$
$$P_h = P \sin i^{1.84 \cos i}.$$
$$P_v = P \cot i \sin i^{1.84 \cos i}.$$

(See "*Iron Bridges and Roofs*," Unwin, p. 120, also, "*Elements of Graphical Statics*," DuBois, Art. 11.) If the wind blows horizontally, and if $P = 40$ pounds, then

For $i = 20°$ we have $P_n = 18{\cdot}1$, $P_v = 17{\cdot}$, $P_h = 6{\cdot}2$.
For $i = 30°$ we have $P_n = 26.4$, $P_v = 22{\cdot}8$, $P_h = 13{\cdot}2$.

Now in the case under consideration, $i = 26° 34'$ nearly, therefore we have $P_n = \frac{18{\cdot}1 + 26{\cdot}4}{2} \times 6{\cdot}98 \times 5 = 800$ pounds nearly, or the normal pressure at each apex, for $P = 40$ pounds, is about the same as the load upon the roof itself. We have also,

$P_v = \frac{17 + 22{\cdot}8}{2} \times 5 \times 6{\cdot}98 = 700$ nearly, and $P_h = 514$ at each apex.

If now at each apex we have 700 pounds acting vertically downwards, if the wind blows on, say from the left, and if the left end is fixed, the right being placed upon rollers to allow expansion; then the reaction at the left is for the first apex load,

$R_1 \times 50 = 700 \times 43{\cdot}75 - 514 \times 3{\cdot}12$, or $R_1 = 580$.
For the second, $R_2 \times 50 = 700 \times 37{\cdot}5 - 514 \times 6{\cdot}24$, or $R_2 = 525$.
For the third, $R_3 \times 50 = 700 \times 31{\cdot}25 - 514 \times 9{\cdot}36$, or $R_3 = 437{\cdot}5$.
For the centre, $R_4 = \frac{350}{2} - \frac{257}{4}$ or $R_4 = 111$ pounds.

The entire reaction at the left end due to wind, therefore is,

$$R = 580 + 461 + 341 + 111 = 1493 \text{ pounds.}$$

We can now, therefore, form the force polygon of Fig. 3, by laying off in succession, to scale, the apex normal forces of 800 pounds each, viz.: A A, etc., equal to P_1, P_2, P_3, and the last, P_4, $= 400$ pounds. Then drawing the verticals A a and B b, making A a equal to 1493 pounds, and drawing the horizontal a B. The force polygon thus closes, as it should. We have at the left end the vertical reaction A a, and the horizontal force a B. These two forces are in equilibrium with the strains in A 1 and B 1, hence lines parallel to these pieces must close the polygon. Thus we obtain B 1 and A 1, Fig. 3. So we go through the frame, precisely as before, and then

scale off the strains. We thus find B 1 = — 4464 pounds, B 3 = — 3568 pounds, B 5 = — 2680 pounds, A 1 = + 3584, A 2 = + 3480, A 4 = + 2640, A 6 = + 1784, A 6′ = + 1980, also, B 1′ = — 3608, B 3′ = — 2584, B 5′ = — 2232, and A 1′ = + 1688, A 2′ = + 3472, A 4′ = + 2584. And for the diagonals 12 = + 800, 23 = — 800, 34 = + 1208, 45 = — 1016, 56 = + 1608, 66′ = — 1608, 5′6′ = + 320, 4′5′ = — 408, 3′4′ = + 480, 2′3′ = —952 1′2′ = + 800. We can now pick out the greatest of these strains for any piece, and taking it together with the strains already found for dead load, we have the maximum strain in every piece. It will be seen that the strains for wind are very considerable, and should by no means be disregarded. In fact in some roof trusses, the effect of the wind is to *reverse* the strains due to dead load in some of the pieces, which should, therefore, be counterbraced.

We may, if we wish, check the above results, by either of our two methods of calculation, but the operations will be found still more tedious, and in curved roof trusses, very complex and intricate. By the graphic method however, no difficulty is experienced.

VI. Economical Angle.—Let α be the angle between the rafter and tie. Then if u is the load per unit of horizontal length, we have for the compression at foot of the rafter, if s is the span,

$$\frac{us}{2} \sin \alpha + \frac{us}{2} \cot \alpha \cos \alpha.$$

But the length of the rafter is $\frac{s}{2 \cos \alpha}$, hence,

$$\frac{s}{2 \cos \alpha}\left[\frac{us}{2} \sin \alpha + \frac{us}{2} \cot \alpha \cos \alpha\right] = \frac{us^2}{4}(\tan \alpha + \cot \alpha),$$

represents the weight of the rafter. Differentiating and putting the first differential coefficient equal to zero, we have $\frac{1}{\cos^2 \alpha} - \frac{1}{\sin^2 \alpha} = 0$, or $\tan \alpha = 1$, or $\alpha = 45°$. Therefore, 45° is the most economical angle for a girder of this kind with straight bottom flange.

If the rafter is considered as a beam continuous over five supports, as strictly it should be, this result is somewhat altered, and we have $43\frac{1}{2}°$ as the angle of economy. In both cases the bracing is disregarded, as it is theoretically nearly constant. In reality, long compression members need extra material for stiffening, and hence our result is not strictly correct.

The above completes our discussion of the problem proposed. We trust that the attentive reader, interested in such questions, will be

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Fig. 1.

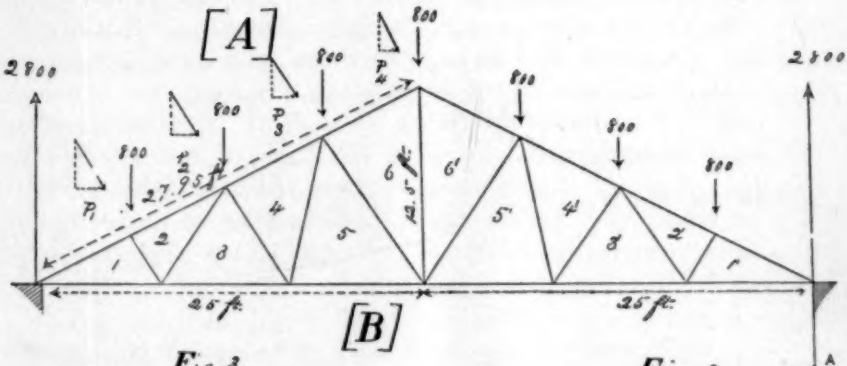


Fig. 3.

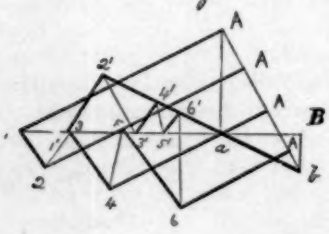
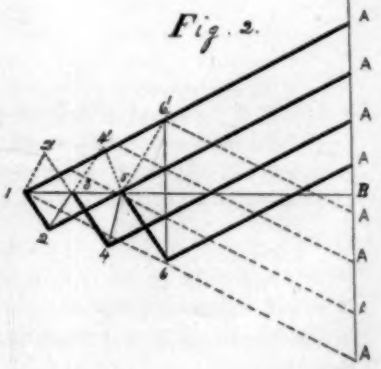


Fig. 2.



Scale of length, 12 ft. to an inch.
Scale of force, 3200 lbs. to an inch.

able to apply now the above principles for himself to any case that may arise. . There are certainly several points of more or less importance which we have been unable to touch upon, but none which he will not, we think, be able to settle for himself. We have scarcely been able to more than hint at the graphical method based upon our second principle, Art. III, and yet it is upon this that the real method of graphical statics properly rests. Should the above serve to call attention to this branch of engineering science, which is at present attracting so much attention, our purpose will be abundantly accomplished.

The literature of the subject in English is already sufficiently extended. In the work of *R. H. Bow*, already quoted, a large number of diagrams for various forms of roof trusses will be found. Once familiar with the fundamental principle, the reader will find no difficulty in following through such examples at sight. In the *Engineering News* will be found a series of very excellent articles, by *Prof. Chas. E. Greene*, in which "Maxwell's Method," as applied to roof trusses, will be found very clearly and thoroughly elucidated. The same author has also in a work entitled "Graphical Method for the Analysis of Bridge Trusses," giving an original, and in many respects, very practical solution for continuous girders and draw spans. In German we have the works of Culmann, Bauschinger and Winkler. In French, of Levy. In the work of the author, entitled the "Elements of Graphical Statics," will be found a thorough presentation of *all* the various graphical methods, together with a complete list of the literature upon the subject, and applications to the continuous girder, draw span, braced arch, etc., illustrated by numerous practical examples.

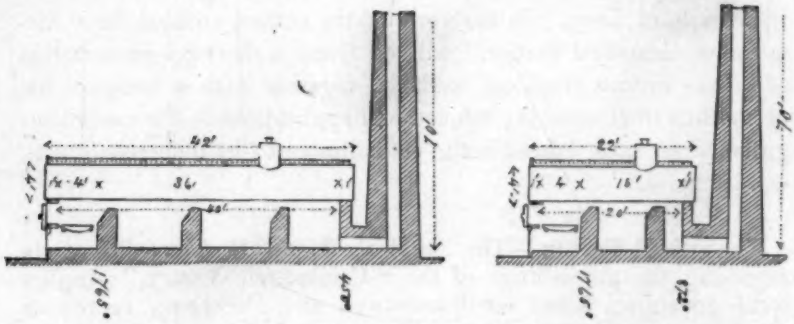
Technical Terms.—The *Camberwell and Peckham Times*, in reporting the proceedings of the "Camberwell Vestry," (Anglice local governing board for Camberwell and Peckham), represents the following colloquy to have taken place during a discussion of a proposal to plant certain roads in the parish with trees, viz: "Mr. Grummant estimated the expense of the trees as being about 100*l.* He said that every tree would require a cradle, and then the ground round about would have to be paved with half sovereigns," (laughter). The surveyor explained that the term "half sovereigns" meant small "pitchers." Mr. Weller, amidst much confusion, protested against the term "half sovereigns" being applied to the stones when there was a proper name (*i. e.*, small pitchers) that might be used. Mr. Wesson (chairman): "Sit down; you shall have the order."—The *Builder*, London, Feb'y 5th, 1876.

STEAM BOILERS AND CHIMNEYS.*

The Relations of Grate Surface to the Horse Power and Chimney Dimension of Stationary Steam Boilers.

By Robert Briggs, C.E.

Some years since a Committee of the Franklin Institute, in a preliminary report upon the horse power of steam boilers, attached the largest importance to the extent of grate and adequacy of the chimney and flues, to burn the fuel; with a minor estimation of the value or effect of heating surface, only insisting that such surface should, by right, be capable of producing a certain economy of evaporation. These propositions were obvious, at least to one of the members of the committee, and were generally conceded by the others; so that no demonstration was then thought necessary; but it appearing at this time that these opinions should be supported by data, the following examination of the subject is offered:



Let it be supposed that there are taken, for examples, two plain cylindrical boilers, the first 42 ft. × 4 ft. diameter, and the second 22 ft. × 4 ft. diameter; each of these boilers are to have 4 ft. × 4 ft. = 16 square feet of grate, and the settings are to be so made as to take off 1 ft. at each end, so that 40 ft. long of the first, and 20 ft. of the second, will be exposed as heating surface, either directly

*Journal Franklin Institute, new series, Vol. xcii, (July, 1871), page 91.

to the fire, or to the gases of combustion. Let it be further supposed that each of these boilers have chimneys 70 feet in height, and 1½ feet of cross area, and that baffling bridge walls be suitably built to insure contact of gases, and that in every respect, except the heating surface, the boilers be placed upon equality of arrangement.

The longer of these two boilers will then be a fair specimen of a plain cylinder boiler, of approved proportions, in all regards (except possibly the chimney section, the size of which will be qualified hereafter). The ratio of heating surface to grate surface will thus be 15 or 16 to 1, which is that usually adopted for boilers of this kind; it can, therefore, be confidently assumed that the grate of this boiler will burn with ease, *by good firing*, 12 pounds of egg or steamboat anthracite coal, exclusive of any ashes or cinders, per square foot of grate per hour; and that the heat proceeding from the combustion, will be absorbed to the extent, that the gases of combustion will escape up the chimney at about 450° Fah., when steam of 60 lbs. pressure, or 305° Fah., is generated from the water in the boiler.

In estimating the effects of combustion under this boiler, the total heat from a pound of the fuel may be taken at 15,000 units, less 10 per cent. for imperfect combustion, or 13,500 units, and the proportion of 24 pounds of air to each pound of combustible, will be accepted; and it will then be seen, after making up the figures, that the gases of combustion at 450°, air being taken at 60°, will carry off 2300 units of heat, leaving 11,200 units as the available quantity imparted to the boiler; or the equivalent to 11·6 lbs. of water evaporated for each pound of coal burnt upon the grate, supposing that no heat is lost in heating up the setting, or given out (lost) from boiler or setting.

If now it be admitted that one-fourth of the heat proceeding from the fire, is given out in the fire place by immediate radiation and conduction, to the boiler over the fire, it will be found by calculation that the temperature of the twenty-four pounds of gases of combustion, when passing over the bridge wall of the furnace, will be 1765° Fah. This supposition of the giving out of one-fourth of the heat by radiation is probably very close upon the existing fact for *under-fired boilers*, when the grate is far enough removed from the boiler for the proper ignition of the coal, and also of the evolved combustible gases between the surface of the coal and the boiler. For fire-box boilers, probably one-third the heat is dispersed in the fire box.

Taking, therefore, 1765° as the temperature of the gases passing the fire bridge, and 450° as the temperature of the gases escaping into the chimney, and 305° as the temperature of the boiler, it results that the loss, or giving out of heat at any intermediate points in the length of the boiler (36 feet), will be proportionate to the differences of temperature at those points, giving the temperature of the flames or gases as follows:

At the fire-bridge,	1765°,	20 ft. away,	711°,
2 ft. away,	1589°,	22 "	662°,
4 "	1425°,	24 "	619°,
6 "	1300°,	26 "	581°,
8 "	1179°,	28 "	548°,
10 "	1073°,	30 "	519°,
12 "	980°,	32 "	494°,
14 "	900°,	34 "	470°,
16 "	828°,	At the chimney,	450°.
18 "	766°,		

It now remains to be shown what will be the effect of removing one-half of the convective surface of the boiler, or in other words, what happens, if the same grate, setting, chimney, etc., and equal *care* in firing, is applied to a boiler; with 16 ft. length of shell, behind the bridge wall, in place of 36 ft.;—with a total length of exposed fire surface of 20 ft., in lieu of 40 ft. It is at once obvious that, without noticing any other effect of the change upon the process of operation, the escaping gases would enter the chimney at 828°, instead of 450°, causing a loss of 378° of heat at this point, which corresponds to the loss of 2255 units of heat above what before occurred, or about 20 per cent. of the total heat available for making steam from the fuel. But the effect of thus heating the chimney will be to increase the draft, and to accelerate the combustion; and as the loss here stated, will appertain to any increased quantity of coal which may be burned, as well as to the normal quantity assumed for the 40 ft. boiler; it will be requisite to demonstrate that 24 per cent. more coal will be induced to burn upon the grate by such increased draft, to provide the *same* quantity of heat to the water of the 20 ft. boiler, as was assumed for the 40 ft. boiler.

An examination into the conditions of the draft of chimneys shows some curious anomalies of figures. The source of power for the draft of a chimney is the difference of weight of the column of heated gases, as compared to that of the same column of atmospheric air,

(which is here assumed at the temperature of 60°). Between 450° and 900°, the velocity of efflux of gases of combustion, under the inducement of the pressure given by the difference of weight of the column, compared with that of air, is such that, in consequence of the increase of volumes at different heats, a very nearly constant *weight* of gases will be expelled for any given interval of time. The combustion of 12 lbs. of coal per hour, with a ratio of one-twelfth of a square foot of chimney to the square foot of grate, and with the supply of 24 lbs. of air to the lb. of coal, is equal to the passage of one pound of gases per second through a square foot of chimney. But a computation gives the time for the passage of one pound of gases, by the inducement of a 70 ft. high chimney:

At the temp. of	450°	500°	600°	700°	800°	900°.
Time in secs., dec.,	0·401	0·397	0·393	0·394	0·397	0·401.

This gives the effective force of the chimney for passage of gases, neglecting all frictions or sources of resistance, as a constant of 2½ times what is needed, [height 4¼ times greater than requisite].

Although the chimney is the source of draft, and its proper dimensions for the passage of the gases an essential element in the calculation, the resistances to be taken into account are: first, that of the entrance of air through the grate and coal; next, that of the passage of gases over bridge walls, and around corners; and finally, that of the chimney flue. Of these three the resistance of air supply to the grate and through the coal is much the largest.

It has been shown that for the supposed chimney and rate of combustion, two-fifths of the effective power of the levity of the gases will have been absorbed in giving motion to the gases themselves; leaving three-fifths to overcome the other resistances. The rate of passage of the air through the grate, can also be estimated by the effect of the difference of the weight of columns, and the result proceeding therefrom, under differences of temperature, will be found quite different from that of the passage of the gases, as the density and volume of the air is constant, while the weight of the chimney columns vary. Upon the same grounds of combustion, chimney, etc., and with the assumption that the interstices of the coal are equivalent to the area of the chimney, (that is one-twelfth the area of the grate—a low estimate), the time of passage through the coal of the

24-25ths pounds of air, needed each second to burn the 1-25th pound of coal, is

For chimney temp. of	450°	500°	600°	700°	800°	900°.
Time in secs., decimals,	0·297	0·287	0·270	0·259	0·251	0·243.

This gives the effective force of the chimney, for the passage of air through the interstices of coal, when all frictions or sources of resistance are neglected, as a variable quantity, of from three to four times what is needed, [or an excess of height of this chimney of from 8 to 15 parts].

The proportions of chimney to grate, and combustion assumed, are those which have resulted from practice, *where the proper constant for resistance of passage of gases in the chimney or flues is not added*. If the cross area of the chimney is taken at 0·7 the area of the grate, divided by the square root of the height of the chimney, and a half square foot of area be added to equalize the frictions of the sides; an approximate rule for the least area desirable, will be obtained, for square or round chimneys, sufficiently accurate for practice. In treating of the capacity of such a chimney, for the flow of gases, or for inducing the entrance of air, the *constant* area should be neglected.

The rate of combustion, and the relations of temperature, all refer to the example here offered, and the excess of power of the chimney, both for passage of gases, and for entrance of air, is expended in the various resistances. It has been shown that at 450°, the gases formed in one second would pass, if free to do so, in 0·401 seconds, and the air enter in 0·297 seconds; while at 872° the gases would pass in 0·399 seconds, and the air enter in 0·247 seconds; it can, therefore, be safely assumed, that at 872°, more air could be made to enter and more gases pass away, in a ratio compounded from these figures; that is, as 0·401+0·297 : 0·399+0·248 : : 1·08 : 1·00. In other words, about 8 per cent. more coal would be burned upon the grate if the chimney were heated to 872°, than if it were heated to 450°. Making a little allowance for the friction upon the reduced length of the boiler, the rate of combustion would be 13 lbs. of coal per square foot of grate per hour, in place of 12 lbs. This rate of combustion would, of course, increase the volume and velocity of flow of the gases, and each two feet length of boiler, at which the table of temperatures has been estimated, would become two and one-twelfth feet, and the gases would then, at the distance of sixteen feet

from the fire bridge, have the same temperature as they would have had with the primary velocity at the distance of fourteen and three-fourths feet. By interpolation, it will be found that this new temperature for the chimney will be 872°, as has been assumed.

The combustion of 13 lbs. of fuel, at 13,500 units, will give 175,500 units, the loss of heat up the chimney from the escaping gases at 872° (= 812°, above original temperature of 60°) = 10,556°, lbs. of coal × 5·94 (= specific heat of the 25 lbs. of gases to each pound of combustible) = 62·703 units; leaving 112·797 units as the result from the 13 lbs. of fuel. On the other side the combustion of 12 lbs. of fuel, at 13,500 units, will give 162,000 units; the loss of heat from escaping gases at 450° (= 390° above original temperature of 60°) = 4680°, lbs. of coal × 5·94 = 27,799 units; leaving 134,201 units. From this it appears that the removal of 20 feet from this boiler would impair its heating capabilities, *per square foot of grate*, a little less than 16 per cent.; and that thus the reduction of the total heating surface to 50 per cent. would be accompanied by the reduction of capability to 84 per cent.

The two suppositions, which produce this result, are: first, the giving out of one-fourth the entire heat, at the fire place; and second, the acceleration of maximum rate of combustion from 12 to 13 pounds per square foot of grate per hour. As to the first of these, no positive authority exists. Peclet ("Traité de la Chaleur") estimates one-half the heat of a fire, from some kinds of fuel, as what is given out by immediate radiation, when surrounded by surfaces of absorption, but his experimental furnace was a toy. Many imperfect experiments on a larger scale, have given for fire box boilers a temperature, for the gases back of the bridge, which would be equivalent by calculation, to the abstraction of rather over one-third of the heat of the fuel for this kind of surface; and it is thought by the writer that the assumption of one-fourth, is certainly *within* the actual dispersion of heat, for under-fired boiler furnaces. While the writer concludes, therefore, to adopt this ratio, he calls attention to it, that any reader may, for himself, value the effect of either increase or decrease in this proportion. As to the acceleration of rate of combustion by increased draft, the figures taken are unquestionably within the rate of actual occurrence. The largest resistance to the draft, is the passage of air through the coals upon the grate; and the assumption that there exists an equality of *resistance* between the coal passage and

the flue passage, on which this increase of coal burned from 12 to 13 pounds is founded, is as favorable to the *least* rate of combustion (or 13 pounds) as possible. [If the rate of combustion for the short boiler were taken at 14 lbs. (which would presume that about two-thirds of the surplus of velocity of the entrance of air was expended in meeting resistance of the coal passage), the heating capabilities of a square foot of grate of the short boiler, would become about 12 per cent. less than what belonged to the long boiler.]

The relative capabilities here estimated will not be materially changed if the heat proceeding from each pound of fuel is varied; that is, if in place of 13,500 units, (12,000 units), or a less number be taken as the bases; nor would a less rate of consumption than 12 lbs. materially change the result, after the same course of figures is gone through; and in the same way the adoption of a smaller supply of air than 25 pounds to each pound of fuel, will only alter the calculations, without materially affecting the final ratios.

Recurring to the figures again: there are found 3375 units to each pound of coal, as given out in the fire box in any case; and with the short boiler, where the escaping gases pass off at 872°, there is left 5302 units to be taken up by the 16 feet length (behind the grate) of heating surface; while for the long boiler, with the escaping gases at 450°, there is left 7808 units to be taken up by its 36 feet of length; and for the 13 pounds of combustion, on a square foot of grate, there is 64,285 units expended on 16 ft. long, in one case; and 93,700 units on 36 feet long in the other.

With this data it will be possible to tabulate the result for boilers of other proportions of grate to heating surface; noticing the following qualifications: first, the quantity of coal burned per square foot of grate is taken at 12 lbs. This quantity is a proper assumption for the given chimney for the amount consumed in the middle part of a grate surface (as a maximum); but it can be taken as a practical constant of allowance, that a deduction of two square feet of surface, from any total dimension of rectangular grates (of ordinary grate bars) should be made, to compensate for imperfection of cleaning out at the sides and corners. Thus the 4 ft. square grate, supposed as the basis of this inquiry, becomes practically but 14 square feet of efficient area, in lieu of 16 square feet; or to make the combustion equal to the quantity taken, the grate should be increased in width (or length) to 4 ft. 6 in., giving a total of 18 square feet of surface, of which only 16 square feet

come into general average use. This last proportion (of 4 ft. 6 in. width) is, in fact, that generally used in setting a four feet plain cylinder boiler, although open to the grave defect of vertical sides for the fire place. It may be well to observe also that the efficiency of a grate falls off rapidly with increase of length, when over 5 ft. long; and in some degree, when over 4 ft. long. A second qualification is to be made in the chimney or flues cross area. The resistance of passage of the gases in the chimney and flues, is mainly that of the elbows and alterations of section, while it is partly that of friction against the sides. The efforts of writers upon the subject of dimensions of chimneys, have been directed towards *estimating* the value of these resistances, and reducing them to some ratio of the force of draft induced by the heated gases. Owing to the variety of conditions and the divergencies of arrangement and construction, no satisfactory figures have resulted from this course of investigation; and the method offered in this paper is confidently presented as a general one, avoiding much abstruseness of calculation, which can be founded solely upon several assumptions with little basis. But the frictional resistance of long passages is a definite one, and bears a relation to length and to perimeter, and can, therefore, be approximately compensated for or equaled by some ratio or proportion of increase of area. It is proposed to do this by a *constant*, for all areas and heights of chimneys; and an investigation could be made to demonstrate the approximate correctness of the procedure, within the limits of the usual proportions of flues and chimneys for boilers; but such an inquiry would scarcely be interesting reading. If there be added to the cross sectional area of a square chimney of any size or height, one-half a square foot, the resistance of friction will have been reduced to a practical equality of ratio, and the *effect* of the draft due to the height, may be taken as independent of the different surface frictions. The actual area of chimney flue then appertaining to the 40 and 20 ft. boilers, which have been made examples, becomes 1·83 square feet, in place of the 1·33 square feet, on which the figures were based. These two corrections are both in the same direction, and in one way the constant of half of a square foot of chimney may be said to supply the area needed for the constant of two square feet of grate. The effect of the constants upon the final ratios is, however, very different.

TABLE

of evaporative capability of one square foot of grate surface of, and of evaporative efficiency of the fuel burned, under plain cylinder boilers; with surfaces in different proportions to their grates and chimneys—example of 70 ft. high chimney with chimney section = one-twelfth grate area—13,500 units of heat, assumed to be produced by the combustion of one pound of anthracite coal, (= 15,000 total, less 10 per cent. for imperfect combustion).

Whole length of boiler exposed to the fire.	Length of boiler behind the fire bridge.	Quantity of coal burned per square foot of grate.	Temperature of gases escaping up the chimney.	Units of heat imparted to the boil'r	Ratio of *capability* of one sq. ft. of grate, taking the capability of the 40 ft. boiler as unity.	Ratio of *efficiency* of one pound of coal burned upon the grate, taking the efficiency of the 40 ft. boiler as unity.	Ratio of total heating surface pr sq. ft. of grate, assuming 16 diam'er of shell exposed. Grate = to unity.
40	**36**	**12·0**	**450°**	**134,200**	**1·00**	**1·00**	**16·0**
38	34	12·1	470°	133,180	0·99	0·98	15·2
36	32	12·2	511°	131,960	0·98	0·97	14·4
34	30	12·3	546°	130,520	0·97	0·95	13·6
32	28	12·4	583°	128,840	0·96	0·93	12·8
30	26	12·5	623°	126,900	0·95	0·91	12·0
28	24	12·6	666°	124,680	0·93	0·89	11·2
26	22	12·7	712°	122,160	0·91	0·86	10·4
24	20	12·8	761°	119,320	0·89	0·84	9·6
22	18	12·9	815°	116,240	0·87	0·81	8·8
20	**16**	**13·0**	**872°**	**112,700***	**0·84**	**0·78**	**8·0**
18	14	13·1	934°	108,780	0·81	0·74	7·2
16	12	13·2	1000°	104,460	0·78	0·71	6·4

* Reduced 97 units in preparation of table.

Although the investigation contemplated by the title of this article is finished by this table, the relation of cross area of chimney to grate has been shown to be involved in the discussion; and from the data given and accepted as the basis of the calculations, it is easy to tabulate results of even more general value than those pertaining to the relations of heating to grate surface, etc.; and the following table gives the area of cross sections of chimneys, for stationary boilers of from 6 to 40 square ft. surface, with square, or nearly square, grates; and with chimneys from 25 to 140 ft. in height; with the maximum quantity of coal the grates will burn, under best conditions, with such chimneys; and the nominal horse power of the grates calculated for 0·55 square foot of grate per horse power (after deducting 2 square feet of grate surface as inoperative).

TABLE.*

Actual surface of grate.	Maximum quantity of coal burned per hour, at 12 lbs. per foot (less 2 feet of actual area).†	Horse power at 0·55 sq. ft. grate (less 2 ft.).‡	PROPER SECTIONAL AREAS OF CHIMNEYS for grates of various surfaces. Height of chimney in feet.										
			25	30	40	50	60	70	80	90	100	120	140
6	48	7·07	1·06										
7	60	9·09	1·20	1·14									
8	72	10·91	1·34	1·27	1·16								
9	84	12·73	1·48	1·39	1·27	1·2							
10	96	14·54	1·62	1·52	1·39	1·3	1·23						
12	120	18·18	1·90	1·88	1·61	1·5	1·41	1·34					
14	144	21·81	.....	2·03	1·82	1·7	1·59	1·50	1·44				
16	168	25·45	.....	.....	1·93	1·9	1·77	1·67	1·60	1·53			
18	192	29·09	.....	.....	.....	2·1	1·96	1·84	1·75	1·68	1·62		
20	216	32·72	.....	.....	.....	.....	2·14	2·00	1·91	1·83	1·76	1·65	
22	240	36·36	.....	.....	.....	.....	.....	2·17	2·07	1·98	1·90	1·78	1·66
24	264	40·00	.....	.....	.....	.....	.....	.....	2·22	2·12	2·04	1·91	1·78
28	312	47·27	.....	.....	.....	.....	.....	.....	.....	2·27	2·32	2·16	2·01
32	360	54·54	.....	.....	.....	.....	.....	.....	.....	.....	2·60	2·42	2·25
36	408	61·81	.....	.....	.....	.....	.....	.....	.....	.....	.....	2·67	2·47
40	456	79·08	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2·71
1 ft. grate without constants.			0·1400	0·1278	0·1107	0·0990	0·0911	0·0837	0·0783	0·0738	0·0700	0·0639	0·0582

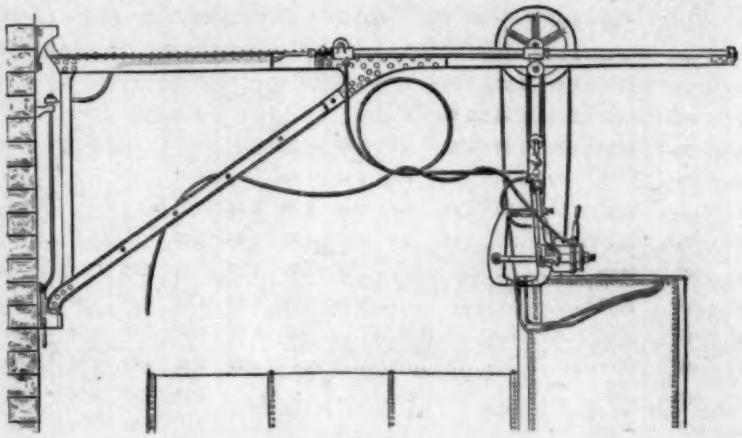
* The figures given in this table can be referred to coal burned, when less quantities than 12 lbs. per square foot are burned, by taking the actual quantity burned in the second column, and finding the corresponding area of chimney, independent of the grate altogether.

† The quantity of coal *shoveled upon the grate*, in yielding the nominal horse power assumed, will have been 10-12ths that given as maximum in this column.

‡ This ratio of 0·55 square foot of grate is supposed to represent the evaporation of one cubic foot (59·48 lbs.) of water from and at 212° per hour, or 57,458 units of heat, and consequently only 104,447 units of heat are assumed to result from the fuel burned on each square foot of grate. The maximum figures given in the table for the 40 ft. long boiler, burning 12 pounds of coal per hour, is 134,200 units, a figure 22·2 per cent. in excess of this assumption as data for horse power. This difference can proceed either from less perfect combustion or less active firing—probably the latter; and if so, the average combustion will have been taken at 9½ lbs. of coal burned per square foot of grate, or about 10 lbs. of coal shoveled into the fire per hour—a supposition not far removed from the desirable rate, from which should be estimated the production of a horse power, with certainty and ease, with the use of any kind of coal.

TWEDDELL'S PORTABLE RIVETTER.*

The accompanying illustration shows the arrangement of Mr. Tweddell's well known portable hydraulic rivetter, which has been at work now for some months at the London and Northwestern Railway locomotive shops, at Crewe. Mr. F. W. Webb has for some time been



considering the best method of doing such portions of the rivetting of locomotive boilers as cannot be done in the fixed rivetters, and is, we understand, well satisfied with the working of the above machine. The arrangement is so simple that not much description is needed. An ordinary swing crane has attached to it a hydraulic sleeve or outer cylinder, which is moved along a fixed tube or pipe by means of a pinion worked by a sprocket wheel, this pinion gearing into a rack attached to the crane. The water, which is supplied under a pressure of 1500 lbs. per square inch from one of Tweddell's differential accumulators, is taken from the main laid along the shop wall, and thence up the centre on which the crane radiates. Thus any motion caused by swinging the crane is reduced to a minimum, and a swivel joint almost frictionless causes no twisting strain to be imparted to the pipe. After leaving this joint the pipe is led along the jib, as shown. There is a communication between this fixed pipe and

* This claim for superiority of "hydraulic" pressure rivetting is not warranted in fact, as against other pressure rivetting, but fully attaches to the inferiority of *hammer* rivetting, either by hand or by steam.—Ed. of the JOURNAL.

the larger one which slides on it, and this sleeve or sliding tube is balanced. A very similar arrangement is used by Mr. Webb in some of his rolling mill patents.

The rivetter is hung from one end of the sliding sleeve, and the pipe conveying water to it from the other. The water is then, by means of a simple frictionless universal joint, led into the machine, which is free to turn completely round in a horizontal plane. The raising or lowering is done by Weston's blocks, and the angle of the machine jaws can be altered from vertical, as shown, to horizontal, by the quadrant in the suspending gear. It will be seen that there is no strain on any of the pipes, and the great difficulty in transmitting the pressure to a rivetter, or other machine in a portable form, is overcome.

The saving in cost of rivetting by this method over the present mode is about four-fifths, and the quality of the work is, like all that done by hydraulic pressure, excellent. A similar machine to this one is adapted to the rivetting up the firehole door rings, and another machine is under consideration which will rivet on the manhole and steam domes. It can then be said that practically every rivet in a boiler will be machine closed, since the machine illustrated this week also rivets on the smoke box tube plates.

The travel of the machine at Crewe is 6 ft. from outer end of the jib inwards; it is also easily arranged by putting the inlet pipe where the rivetter is suspended and the rivetter to where the pipe coupling is, for the rivetter to cover another 6 ft. inwards, in all 12 ft., without any more connections to the main. The whole apparatus is easily lifted by the overhead traveler to other wall brackets, and thus one crane can work a whole shop.

A similar plan is being used for rivetting girders, the crane being of a rougher design, or in many cases the hydraulic gear is easily attached to existing cranes. Girders and other work are done with this machine at Crewe, and very good work by two similar machines is now being done in the large girder and boiler works at Sir W. G. Armstrong's, Elswick, and elsewhere.—*Engineering*, Feb'y 11, 1876.

Engraving on Iron and Steel.—As the result of very many experiments, Professor Kick recommends the following solution for engraving iron and steel, to show the grain, etc.:—Equal parts of hydrochloric acid and water, with a trace of antimonial chloride.

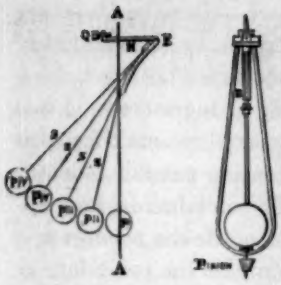
THE RESULTS OF SOME EXPERIMENTS WITH HUYGEN'S PARABOLIC PENDULUM FOR OBTAINING UNIFORM ROTATION.

By R. L. J. Ellery, F. R. S., F. R. A. S., etc.*

In the course of some experiments I made about two years since with the view, if possible, of obtaining more uniform rotation for our barrel Chronographs than had hitherto been secured, I was induced to try Huygen's revolving Parabolic Pendulum, which appeared so perfect theoretically, that I surmise as the reason it had not been more generally adopted that there must be some great practical difficulty pertaining to the application of the principle.

I was somewhat surprised too, on looking into the literature of the subject, to find so little information; and in the books within my reach in Melbourne no record of any experiments or precise trials of this kind of pendulum for securing uniform rotation. I had, therefore, nothing to guide me in my experiments except the bare principle. The earlier results I obtained were so unpromising that my idea that there must be some fatal practical difficulty in the way was strengthened. Eventually, however, I succeeded in obtaining results, and under trying tests, which satisfied me that the pendulum would, with moderately precise workmanship and careful adjustment, become an almost perfect Governor where the variations of force are not greater than we generally have in chronograph trains, or, indeed, in well-constructed and balanced Equatoreals; and in two Chronographs which I had constructed for the Transit of *Venus* observations and which were controlled by parabolic pendulums, the rotation of the barrels were practically uniform, even when such a variation of the driving weight was made as to produce a difference of 20° in the arc of the rotating pendulum. When I say *practically uniform*, I mean that, on a barrel rotating once in a minute for two hours and a half, *all similar second marks* were in an absolute straight line, and that with a fine drawing pen and a straight edge a line could be drawn accurately bisecting each second mark; in other words, its secondary rate was not a tenth of a second in two hours. As the principle of Huygen's Parabolic Pendulum may not be generally known among our members, I would beg to refer to these diagrams:—

*From the monthly notices of the Royal Astronomical Society, December, 1875.



Let A A be a vertical axis of rotation which can be driven by clockwork acting at the top or the bottom of the axis; from this axis a pendulum P is suspended in such a way that when it hangs vertically the string S lies wrapped over a curved surface E, which forms part and parcel of the vertical axis. This curve is the evolute of a parabola, whose distance from vertex to focus is half the length of the required pendulum. Now let the axis revolve and the pendulum will fly out from its vertical position, more or less, according to its weight and the driving power; the arc described by the pendulum, as it increases its distance from the vertical, will be a parabola, by reason of the string gradually unwrapping from the evolute E. Now, from the properties of the parabola, it follows that the vertical distance between the centre of rotation of the pendulum P and the intersection of the string S with the axis of rotation of the pendulum will remain constant, and therefore that the length of the pendulum remains constant at whatever arc it may rotate.

To practically secure these conditions it is necessary, first, that the evolute shall be properly and precisely made, and secondly, that it shall be so adjusted that the axis of the evolute and involute shall be coincident with the axis of rotation.

The pendulums I had constructed are *half seconds*, that is, rotating once in a second. They are suspended in a hard gun-metal frame, pivoted at top and bottom, the lower pivot resting on an end jewel, the upper pivot supported by a strong cast iron gallows bracket, and it is driven by a contrate wheel in the clock train engaging into a pivot at the lower end of the frame. The frame is open, in the form shown in the right hand figure, to allow of the middle part of the axis of rotation being clear for the evolute and the pendulum string or rod. The evolute is fixed at M, and is capable of adjustment at right angles to the axis of rotation by a screw Q, the proper position of the curve in the other direction being practically secured by careful workmanship, more especially in the construction of the evolute itself. The pendulum consists of a spherical bob, weighing about 2½ lbs., on a steel rod about one-tenth of an inch thick, and suspended by a long and *exceedingly thin* steel spring secured to the top of the evolute at N. The regulation of the length of the pendulum is done in the or-

dinary way by a nut at the bottom of the steel rod. The Governor thus made with ordinary care and workmanship is by far the best of any I have had experience of, and has furnished results better, I believe, than any others used with chronographs; at the same time it is simple and inexpensive. In the course of my experiments I found it quite necessary to use the most flexible suspension possible, and the thinnest steel spring made for French clock pendulum springs appears to answer well—it is not liable to twist unless the pendulum is started or stopped suddenly, and this is prevented by a guide for the bottom of the pendulum rod. To get the proper position of the evolute:—If the time of rotation increases with an increase of arc, in other words, if it revolves slower for increase of arc, the axis of the evolute is beyond the axis of rotation, reckoning from the centre of oscillation of pendulum (that is, it is too far away from pendulum bob); and it is too near if it revolves more rapidly for increase of arc. The adjustment is somewhat tedious, more especially because for every alteration, however slight, of the evolute, a large alteration of the length of pendulum is requisite—but it is easily done with a barrel chronograph by increasing and diminishing the driving power and noting the effect, on the rate, of increased and diminished arcs of pendulum. The screw which adjusts the evolute should be moderately fine, as the final touches necessary to get accurate performance will be found very small. I found a good deal of trouble in the course of my experiments from small particles of dust getting between the curve and spring, and it will be found quite necessary to protect the pendulum from this source of imperfect performance.

I had an opportunity of testing one of these chronographs in the presence of Professor Harkness, of the Washington Observatory. It was allowed to go for about an hour, then the weight was doubled for half an hour, and subsequently halved—the arc of the pendulum varying from 10° to 33° under these changes, but the *lines of seconds* on the barrel were quite undisturbed, and a fine straight line could be drawn so as to bisect every similar second mark. Professor Harkness was somewhat astonished and pleased with the result. I showed one or two sheets marked by this chronograph to Sir George Airy, Mr. Christie, Mr. Dunkin, and Captain Tupman, and I intended to show them at the meeting of the Society, but I unfortunately mislaid them. I have no doubt, however, these gentlemen will remember the exceeding precision with which the sheets were marked.

It may be said, however, that such great precision is unnecessary, especially in astronomical chronographs, and that any of the ordinary means of obtaining moderately uniform rotation are sufficient for astronomical purposes. I shall be in a great measure inclined to agree with such an opinion, but not altogether, for these reasons. This Governor, which gives nearly perfect results, is simpler and cheaper than nearly all those which only aim at very moderate accuracy; and again, any one who has had much to do with *reading off* chronograph sheets or fillets will, I am sure, agree with me that *time is saved enormously* where *a scale* of minutes and seconds can be applied to the register, which can only be done with confidence where the rotation has been uniform. In an Observatory where much transit work (especially in Zone-observing) is done with aid of the chronograph, as at Melbourne, any means by which *reading off* can be expedited is of much more value than many would be inclined to imagine. Again, a simple means of obtaining accurately uniform rotation will be of great value in driving siderostats, and in many physicial and physiological experiments; and I do not imagine there would be any great difficulty in applying this method to governing the driving apparatus of Equatoreals, the uniform motion of which, I believe, yet remains a thing to be desired.

I have on the table an apparatus, a kind of Morse's telegraphic register, governed by a parabolic pendulum, which will illustrate my description. It is devised to draw a paper fillet over rollers with great uniformity for chronographic purposes.

Cornish Pumping Engines.—The following is extracted from the *Mining Journal* of January 29th, 1876: The number of pumping engines reported for December is 17. They have consumed 2076 tons of coal, and lifted 15,600,000 tons of water 10 fms. high. The average duty of the whole is, therefore, 50,800,000 lbs., lifted 1 foot high, by the consumption of 112 lbs. of coal. The following engines have exceeded the average duty.

Crenver and Wheal Abraham—Sturt's 90 in.		Millions	59·7
Ditto	Ditto —Pelly's 80 in.	"	52·7
Ditto	Ditto —Willyams' 70 in.	"	78·4
Dolcoath—85 in.		"	59·4
West Basset—Thomass' 60 in.		"	54·5
West Tolgus—Richard's 70 in.		"	52·4
West Wheal Seton—Harvey's 85 in.		"	57·2

Chemistry, Physics, Technology, etc.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS DURING THE LAST TEN YEARS.*

By Dr. A. W. Hofmann.

From the *Chemical News*.

[Continued from Vol. ci, page 213.]

The three last named methods may be considered as adapted for industrial purposes. As the peroxide of hydrogen does not solidify at — 30°, its solutions may be concentrated by cooling them below 0°, and allowing the water to freeze out. For this purpose Houzeau makes use of the apparatus of Carre.† A great difficulty in the way of the commercial preparation of peroxide of hydrogen lies in its instability. This substance requires to be preserved in well-closed vessels and in acidulated solution, and even thus it requires great caution. Wood-charcoal and certain oxides and metals, especially silver, gold, and platinum in a state of fine division, decompose it by mere contact.

That it is a powerful oxidizing agent, and that it even in the cold converts arsenious into arsenic acid, sulphide of lead into sulphate, and the lower oxides of manganese, iron, cobalt, barium, strontium, and calcium into the highest oxides of these metals, and that it once completely oxidizes arsenic and other elements, is not remarkable. But the more interesting and surprising are the observations of Thénard, extended and explained by Brodie in 1850, and shortly afterwards at Schonbein, according to which the peroxide of hydrogen acts not merely as an oxidizer, but as a powerful reducing agent; that it converts iodine into hydriodic acid,

$$I + H_2O_2 = 2HI + O_2,$$

* "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

† Houzeau *Monit. Scient.*, 1868, 175.

that it separates metallic silver from silver oxide,

$$Ag_2O + H_2O_2 = Ag_2 + H_2O + O_2,$$

and reduces peroxide of manganese to manganous oxide,

$$MnO_2 + H_2O_2 = MnO + H_2O + O_2.$$

In these reactions two atoms of oxygen coalesce to one molecule, which explains this strange phenomenon. At times, peroxide of hydrogen acts almost simultaneously as an oxidizer and a reducer. Thus it converts chromic acid, CrO_3, transitorily into perchromic acid, which is very soon resolved into chromic oxide and free oxygen. If we, therefore, add to peroxide of hydrogen a few drops of a solution of chromate of potash and a little hydrochloric acid, and shake up with ether, the latter is colored a deep blue by perchromic acid, but soon (especially if no ether is present) oxygen escapes and green solution of chloride of chromium remains. Similarly both actions appear simultaneously when solutions of ferrous sulphate and indigo are mixed with peroxide of hydrogen. The ferrous oxide is transitorily peroxidized and then again reduced, whilst the oxygen is transferred to the indigo and decolorizes it.

By these effects of oxidation and reduction, both of which it displays in the highest degree, the industrial sphere of the peroxide of hydrogen is marked out. These effects, although mutually antagonistic, answer the same purpose for a certain practical operation, *i. e.*, bleaching sulphurous acid and zinc powder, powerful reducers, as well as chlorine and ozone, powerful oxidizers, are all used as bleaching agents. How much the rather can this function be assigned to peroxide of hydrogen?

Thénard, on bringing peroxide of hydrogen into contact with his tongue, in order to ascertain its taste, found that it was whitened. The cuticle was also blackened, and at the same time a violent itching was excited. Litmus paper without any previous reddening was at once decolorized, as was also turmeric paper.

In 1863, Chevreul* undertook comparative experiments on the bleaching power of hydrogen peroxide. Its concentrated solution speedily turned syrup of violets, green, oxygen being set at liberty. For the following experiments dilute color solutions were used

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* Chevreul, *Comptes Rendus*, lv, 785.

—namely, syrup of violets, tincture of litmus, extract of peach wood, and extract of logwood. The results were as follows:

Time.	Violets.	Litmus.	Peach Wood.	Logwood.
10 mins.	Imperceptible.	Slight bleaching.	Change to rose.	——
24 hrs.	Complete bleaching,	Almost complete bleaching,		Turns yellow.
80 hrs.	Complete bleaching of all the solutions.			

Decolorization is therefore effected less rapidly by peroxide of hydrogen than by chlorine. Tessié du Motay and Maréchal* mention it as one of the agents which they propose for bleaching tissues, which, after treatment with permanganate of potash, they recommend to be steeped in a solution of peroxide of hydrogen. But it had been much earlier applied as a bleaching agent by Thénard† himself for a particular purpose—namely, for restoring old oil paintings and drawings. White lead in old paintings, which has become blackened by the gradual action of sulphuretted hydrogen, is converted into sulphate of lead by dilute solutions of peroxide of hydrogen, and thus restored to its primitive color. A fine drawing by Raffaelle, with superimposed white which had become spotted with black, was completely cleansed by a solution which contained at most five or six times its volume of available oxygen, and the paper did not suffer.

A peculiar, hitherto secret, application of this bleaching agent has been recently made public by A. v. Schrotter.‡§ During the last few years, bottles labeled "Eau de Fontaine de Jouvence, golden," and containing about 140 c. c. of a colorless liquid, have been sold by perfumers in great cities. The price demanded is about 20 francs, and to them, as it appears, is due that offensive blonde shade of hair which holds an intermediate place between ash gray and bright yellow, and attracts the attention of the spectators and the curiosity of observers by its *piquante* unnaturalness. According to Schrotter this secret nostrum is merely a solution of hydrogen peroxide, made stable

* *Bull. Soc. d'Encouragement*, 1867, 472. Dingler, *Polyt. Jour.* cxxc (?) iv, 526.

† Pelouze and Frémy, *Traité de Chimie*, 1861.

‡ *Berl. Chem. Ges.*, 1874, 980.

§ From the correspondence of the *Chemical News*, January 14, 1876, it appears that the composition of this liquid was first published by Dr. Chas. A. Cameron, in the *Dublin Medical Journal*, November, 1869.

by copious dilution, and by addition of a small quantity of acid—apparently nitric acid. According to Schrotter's careful examination it contained 6 volumes of available oxygen; 1000 grms. of the liquid would therefore contain 8·6 of available oxygen, or 18·3 of peroxide of hydrogen. As may be imagined, however, in case of an easily decomposable body, the bottles do not all contain solutions of equal strength. An examination conducted in the laboratory of the University of Berlin, showed, in 1 volume of the solution 9·4 to 9·8 vols. of available oxygen, corresponding to 13·6 grms. O, or 28·9 grms. H_2O_2 per liter. A bottle costing 20 francs yields the purchaser 2·5 to 4 grms. of this substance in solution, and effects its purpose completely, though slowly, within four to six days, thus strikingly illustrating the great efficacy of peroxide of hydrogen. The name of the perfumer who understands how to speculate so successfully upon the purses of his fair contemporaries, and who deserves to be known to posterity, is E. H. Thiellay, of London.

Perhaps Mr. E. H. Thiellay has unintentionally become the founder of a manufacture of peroxide of hydrogen which may have worthier applications in the future. Perhaps he may not be the first or the only hair bleacher, as appears from the following document. What von Schrotter revealed to the public was previously known to the initiated. Thus it appears from a letter of M. Schering, of the Council of Commerce, dated Berlin, July 3d, 1874, in which occurs the following passage:—

"The bleaching of hair, feathers, etc., by means of peroxide of hydrogen has been found practicable, the greatest difficulty being the ready decomposability of the material. In England and France it is prepared and sold for this purpose in quantity under the names 'Golden Hair Water' and 'Auricome.' In my establishment it is often inquired after for the same purpose." Mr. J. Williams, of the firm Hopkin and Williams, of London, makes a similar statement in letters of July 20 and 27, 1874. By peculiar precautions, however, he is able to prepare permanent solutions of peroxide of hydrogen containing 10 to 20 volumes of available oxygen (3 to 6 per cent. by weight of H_2O_2). The weaker solution, which is said to keep for months without change, is sold at 8s. per kilo., in larger quantities at 6s. The stronger solution is sold at double the price. The amount of oxygen in Thiellay's solution, as determined in the Berlin labor-

atory, agrees tolerably closely with the weaker of these preparations, and this may possibly be its true origin. As the bottle when the determination was made had been opened four weeks previously; as it was only half full and was merely provided with a common cork, the permanence of the solution may be considered sufficient for most purposes.

Peroxide of hydrogen would not be the first body whose industrial application commenced with trifles and gradually reached an unimagined extension. Nitrate of silver served first the vanity of the world as a hair dye long before its applications in photography. Schrotter* very rightly expresses the wish that peroxide of hydrogen might be generally accessible at a moderate price. Bottger,† and previously Geiger,‡ recommend its introduction into the pharmacopœia. That for medicinal purposes it is preferable to oxygen, ozone, or ozone water (!) is manifest. Whilst ozone only bleaches ivory in the strongest sunshine of summer, there is no doubt but that peroxide of hydrogen would answer the same purpose even in the absence of light.

Progress in the Artificial Production of Cold and Ice. By Dr. H. Meidinger, *Professor in Carlsruhe.*

Concentrated cold in the form of ice acquired day by day a higher importance for industrial as well as for domestic purposes. Brewing on the Bavarian system, the preparation of "Lager beer," which, amongst us in Germany, at least, has nearly superseded all other kinds of beer, depends upon the prolonged maintenance of a temperature bordering upon freezing point. The confectioner has no other practical means of producing a degree of cold from — 12° to — 18°, as required in the preparation of ice creams. The physician often employs the cold of ice both externally and internally as an absolutely indispensable remedy. The butcher and the hotel keeper can scarcely dispense with this means of preserving meat. In the domestic sphere ice has become formally established, at least in large cities, where it can always be obtained at a cheap rate, and to those who have become accustomed to its use, it appears a necessary agent for preserving food and cooling beverages during the warm season.

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* Von Schrötter, see above.

† Böttger, *Polytech. Notizblatt.* 1873, 13.

‡ Geiger, *Lehrbuch der Pharmacie* aufl. bearb., v. Liebig, i, 213.

In chemical manufactures ice has also found various applications in the crystallization of salts, or, to speak in more general terms, in the separation of dissolved substances by means of cold. In proportion to the growing consumption, we see increasing quantities of ice stored up every winter. An extensive system of transportation has been arranged for conveying ice from the more northern and colder parts of the earth to regions nearer the equator. North America especially ships ice in astonishing quantities in all directions, even to Central and South America, to the West Indies and to India. Ice from Norway is sent to England and the German ports on the North Sea. In mild seasons, such as 1862–63 and 1872–73, ice from the glaciers of the Alps was sent down the Rhine in entire trains.

Science has shown, however, how to prepare the important requisite artificially. The first attempts at the manufacture of ice on the large scale took place between 1850–60; but this branch of industry has since been much extended. Even in regions where the winter is, as a rule, cold enough to permit ice to be stored up in quantity, *e. g.* in Germany, it has often been found remunerative to construct machinery for its artificial preparation, or in general terms, for the production of cold. Manufacturing establishments of this kind may be seen in various places in full activity, and after the mild winter of 1872–73, the demand for machine-made ice could scarcely be met.

The London Exhibition of 1862, introduced the ether and ammonia ice machines. A third system has since been added, the air ice machine, which has not yet reached perfection, since peculiar difficulties interfere with its practical execution. The theories of these machines have been already explained, so that there is no difference of opinion as to their capabilities and their relative merits. A series of proposals have also been made for the production of cold by other agencies, which have hitherto produced little or no practical result. We will endeavor to describe the development which the question has taken in all its branches down to the present day.

The science of physics reveals three procedures by which a reduction of temperature can be effected, ice being the result if the cooling is sufficiently intense and is applied to water. The methods in question are:—The solution of solids (salts); the spontaneous evaporation of liquids; and the expansion of aeriform bodies. Each of these methods has met with practical applications; the first mentioned or solution process for reducing the temperature of small mass in simple

apparatus not acting continuously; the two others, evaporation and expansion, for the uninterrupted production of ice in complicated machines.

1. *Cold obtained by Solution.*

Every mixture of substances in proportion as it produces, during solution, the greatest depression of temperature in its own mass is called a freezing mixture. Various mixtures of this kind have long been known, and may be found described in all text books of physics. The best known and most commonly applied both in domestic and technical affairs pre-supposes the presence of ice. It consists of 3 parts of ice and 1 of common salt, which dissolve each other, whilst the temperature falls to —21°, the freezing point of a concentrated solution of chloride of sodium. The solution of a part only of the mixture is requisite to produce this low temperature in the entire mass. Not till heat penetrates from without into the mass does a further melting take place, the temperature remaining the same. Consequently the above degree of cold may be kept up till all the ice has been melted with the salt. It is necessary, however, to keep the mixture continually agitated. This snow and salt freezing mixture is used in preparing ice creams, for which a temperature of about —12° is required. As the essential point here is the congelation of water and the other substances present may be neglected, as far, at least, as their specific and latent heat is concerned, it is easy to calculate what weights of ice cream may be prepared with a known quantity of freezing mixture.

The freezing apparatus of the confectioners consists of a tin vessel for receiving the ingredients, placed in a larger bath of wood or tinned copper. The interval is filled with ice and salt, which are constantly stirred that the mutual contact of the two may be perfect. If this is neglected, the salt, after a portion of the solution has been formed, sinks to the bottom and ceases to act upon the ice. Since about 1865, a freezing apparatus for domestic use has been introduced from Paris, arranged as follows: A cylindrical pewter vessel with double sides is fitted in the middle of a jacket with two pivots, which rest upon two supports fixed in a block of wood. One of the pivots is prolonged so as to form a handle which serves to keep the cylinder in continual rotation. The two plane ends of the cylinder are discs of wood, which are pressed upon the cylinder by a peculiar arrangement, india rubber rings being used to preserve complete tight-

ness. The interval between the double sides of the cylinder is filled with a bad conductor of heat. A cone of pewter is introduced into the interior, and can be opened on one side to receive the materials for the ice cream; the annular interstice is filled with salt and ice, which are introduced from the other side. The lid is put on, and the handle is turned for about five minutes. The lid of the cream receiver is then taken off, and the matter which has become deposited on its inner sides is scraped off with a spatula and stirred up with a still unfrozen residue to a butter-like consistence. The apparatus is closed again, turned for five minutes, opened again, and the contents stirred up as before—an operation which is repeated a third time. In a quarter of an hour the ice cream is ready. The apparatus acts satisfactorily, but it is troublesome and rather costly.

Dr. H. Meidinger has constructed a simplified machine to which the way has been paved by the observation that a concentrated solution of salt melts ice, producing, if the concentration be preserved, the same low temperature as does the action of solid salt upon ice.* The machine consists of the following three parts: —A cylindrical vessel (cooler) with double sides quite open at the top; secondly, a conical tin vessel (freezer) of about half the diameter of the former, reaching down nearly to its bottom and furnished above with a firmly connected covering plate, which rests upon the top of the cylinder and fits it tightly like a lid; lastly, an annular strainer-like vessel (the salt holder), which is let down into the space between the cylinder and the freezer at about half the depth of the former. The cylinder is charged about half full of pounded ice, upon which is poured a concentrated solution of salt; the strainer filled with salt is then let down, and lastly, the freezer containing the materials for the ice cream is forced in and is in complete contact with the freezing mixture over its whole surface. The ice melts in the solution of salt, which, as it becomes diluted, dissolves more salt from the strainer and thus remains nearly saturated and capable of undiminished action upon the ice. The reduction of temperature throughout the apparatus is equable, and a mechanical movement of the vessel is not required. The needful agitation of the freezing ice cream is performed at intervals of five minutes, without any disarrangement of the apparatus. The machine is constructed by Messrs Beuttenmüller and Co., of Bretten, in an elegant form, fit for the table. Recently

* Meidinger, *Bad. Gew.*, 1872, Beil. No. 6. *Dingl. Pol. J.*, cciv, 409.

it has been applied on a larger scale in perfumery for the separation of fatty oils from spirit.

Freezing mixtures in which a fall of temperature is produced by the solution of salts in liquids have been latterly subjected to examination in various quarters, after different small ice machines for domestic use, adapted to their application, have been introduced into trade. Dr. Meidinger has drawn up a table of 16 mixtures* according to his own experiments. An abstract of this, comprising the most useful mixtures, is given below.

Mixture.	Fall of Temp.	Sp. Heat of Solution.	Sp. Gr. of Solution.	Loss of Heat units for 1 kilo. of Mixture.	Loss of Heat units for 1 liter of Mixture.	Quantities to be used for 120° C. Heat units. Salts. Kilos.	Water. Kilos.	Cost.†
1 Salt. 3 Ice.....	27°	0·83	1·18	125	100	0·5	1·5	0·34 to 0·12
3 Sulphate of soda crystals 1 Conc. hydrochloric acid.	37°	0·74	1·31	55	74	2·7	1·8	1·0 to 0·6
2 Nitrate of ammonia. 1 Sal-ammoniac. 3 Water.	30°	0·70	1·20	42	51	3·0	3·0	7·6 to 6·8
3 Sal-ammoniac. 2 Saltpetre. 10 Water.....	26°	0·76	1·15	40	46	2·1	4·2	2·6 to 2·2
3 Sal-ammoniac. 2 Saltpetre. 4 Sulphate of soda cryst. 9 Water.....	32°	0·72	1·22	50	61	2·5	2·5	1·8 to 1·6

(To be continued.)

ELECTRICAL PHENOMENA.

The Alleged Etheric Force. Test Experiments as to its Identity with Induced Electricity.

By Prof. Edwin J. Houston and Prof. Elihu Thomson.

Since the experiments of Mr. Edison are still believed by some to demonstrate the existence of a force hitherto unknown, we submit the following considerations, together with experiments, which we believe to be crucial in establishing the identity of the supposed new

* Meidinger, *Bad. Gewerbz.*, 1868, 98.

† The cost is given in decimals of a shilling, assuming the shilling to be approximately equal to the German "mark."

force with inverse currents of induced electricity. The alleged necessity for the assumption of the new force being based on its asserted lack of polarity, we propose to show how two opposite phases of the so-called force may neutralize each other, thus conclusively establishing its polarity.

In order to show that, in Mr. Edison's experiments, inverse electrical currents must necessarily exist, notwithstanding the fact that the manifestations occur only at the *opening* or breaking of the circuit, we will discuss his typical experiment in detail. In Fig. 1 we have the well known arrangement for the production of the alleged new force. On the completion of the circuit, the battery current flows as shown by the arrows, and *M* becomes a magnet. On breaking the connection as at *K*, the so-called etheric force is manifested at the points P, in the dark box. It is evident that the above embraces all the essentials of Mr. Edison's experiments. When a battery current flowing through a considerable length of wire, is interrupted by breaking contact as at *K*, a bright spark of appreciable length is seen at the break (*K*). This spark is due to the extra current, and indicates a great increase of electrical tension in the wire, the discharge occurring through an appreciable air space at K. It will be seen that the wire around the magnet is, at the moment of breaking contact, charged with electricity of considerable tension (extra current), positive or negative, according to the direction of the battery current. In Fig. 1, since the magnet wire is connected with the positive pole *C* of the battery, the charge in the wire will be positive, and a negative charge will be accumulated on the general conducting surface of the battery, which thus acts in part to condense the negative charge. This state of tension at once disappears on the discharge of the extra current. The extra current is not produced until the circuit is broken, and its discharge takes place when the wires have been appreciably separated, as shown by the spark. At every break, therefore, the wire surrounding the core of the magnet accumulates a static charge of considerable tension, which is rapidly discharged. This charge, acting by induction on the core of the magnet, induces in it, and in all metallic masses, in connection therewith, a flow or charge in one direction,

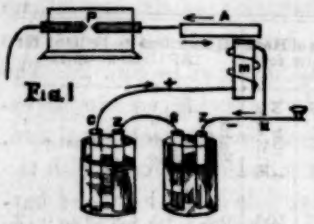

Fig. 1

while the tension in the wire is increasing, followed instantaneously by a flow or charge in the reverse direction for the re-establishment of electrical equilibrium in the cores of the magnet, *consequent on the discharge of the wire itself*, the wire and the cores of the magnets bearing the same relations to each other as the inner and the outer coatings of a Leyden jar. Here, then, we have all that is necessary for the production of the so-called etheric effects, apparent non-polarity included.

In order to prevent the possibility of a charge of any tension remaining in the coils of wire on the interruption of the current, we arranged the following experiment: A battery of eight cells was divided into two sets of four cells each, as shown in Fig. 2. The

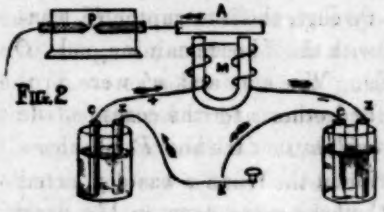

FIG. 2

sounder magnet *M*, used in this experiment, was connected as shown, *i.e.*, one end of the coils with the positive pole of the left hand battery, and the other end to the negative pole of the right hand one. An interrupter placed midway between the remaining poles of each battery furnished the necessary breaks, as at *K*. Under these conditions we could obtain no appreciable spark in the dark box at *P*. In this experiment the magnet is placed so as to occupy the exact middle of the circuit, one-half the wire in the coils being influenced by that part of the extra current which produces a positive charge, and the other half, by that which produces a negative one. When thus arranged the inductive effects of the extra current being equal and opposite, neutralize each other, and hence no inductive spark appears in the dark box *P*. In this experiment, thorough insulation of the batteries, key, and connecting wires, is necessary, in order to secure an equal division of the effective circuit.

The absolute necessity for the equality of the two divisions of the circuit and of the neighboring conducting surfaces, in the above experiment, is shown by connecting any part of the circuit with a conducting surface, as, for instance, a mass of metal, or even the body of the experimenter, when sparks at once make their appearance at *P*. The mere approach of any person, *without* contact with any conducting surface near to any part of the circuit, or to either of the batteries, is followed by a similar result. In this connection it is evident that

any inequality in the metallic surroundings of the halves of the circuit is sufficient to cause irregularity in the results. So necessary is the *equal* division of the conducting surfaces, that even the use of an ordinary telegraphic key at K is sufficient to introduce unequal metallic surfaces into the circuit, and so derange the experiment, and we would therefore suggest that the breaks be made by the conducting wires themselves. If the battery be unequally divided, sparks are seen in abundance in the dark box.

To test the question of the polarity of the alleged new force, the following experiment was devised: The battery terminals were connected respectively with one end of the coils of the magnets M and M' which were exact counterparts of each other. The circuit was completed through the interrupter K, connected with the two remaining ends of the coils. Wires a and a' were provided for connecting the cores of the magnets with the dark box P, at pleasure. When the wire a was connected with P, sparks were seen in the dark box, in breaking the contact at K; similar sparks were seen where the wire from a' was alone connected. When *both* a and a' were connected with the dark box *no spark could be obtained.*

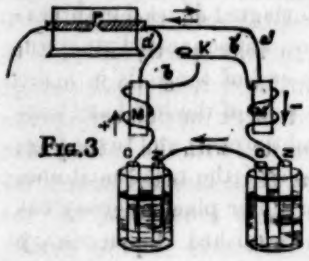

FIG. 3

In the foregoing experiment it is evident that the polarity of the extra current produced in M is the opposite of that in M', representing, as they do, the positive and negative poles continued from the battery. Under these circumstances the induced charges in each core being opposite, neutralize each other, and no spark is seen. Since, however, contact of a or a' with M or M' singly gave all the so-called etheric manifestations, and that when both were connected no spark was obtained, *it is clear that in this experiment is presented unquestioned evidence of that polarity which has apparently been wanting, and which want has thus far furnished the only grounds for the assumption of the discovery of a new force.*

That the non-appearance of the spark at P was due to an exact neutralization of the two opposite phases of the "etheric force," is shown by bringing any conducting surface, as the finger, into contact with any part of the circuit, as at b or b', when sparks at once appeared at P.

We found that it was not necessary to employ cores surrounded by coils of wire to produce the so-called etheric force. We note the following experiment: a hollow cylinder of non-conducting material as a test tube was covered on the outside with a sheet of metal. A metallic bar was placed inside the tube, and from it a wire was led to the dark box. On connecting the exterior metal surface with almost any portion of a long battery circuit, which was interrupted, sparks were seen in the dark box at every break. These sparks possess all the properties claimed for the "etheric" sparks. In this case no person at all familiar with electrical induction would for a moment question the true origin of the sparks seen in the dark box.

Metallic coatings are not necessary to produce the effects just described. In the following experiment we replaced them by liquid surfaces: In a tumbler partly filled with slightly acidulated water, a test tube is placed, also filled with acidulated water. The wire *W*, connected with the battery wire *B*, interrupted at *K*, is inserted in the test tube. The wire *S*, in connection with the dark box, dips into the liquid in the tumbler. On interruption of the circuit, sparks appear at the dark box *P*. Comment is unnecessary.

FIG. 4.

It may be interesting to state that the foregoing experiments were thought out in accordance with the known laws of electricity and the results fully confirmed our expectations. It is hoped that the foregoing experiments will have established still more decidedly the fact that *all the manifestations classed as "etheric" are due solely to inverse currents of induced electricity.*

ANTHRACITE METALLURGICAL COKE.*

The desirability of avoiding the introduction of sulphur into the metal at any point of the process of manufacture has led iron and steel makers to give the utmost attention to the selection of fuel, and to make numerous experiments, but it frequently happens that a fuel offering advantages in one direction has more than equivalent disadvantages in another. It may be to this fact that the non-introduction of peat and of anthracite coal as metallurgical fuel may be attributed,

* From the *Mining Journal*, London, March 11, 1876.

for peat is known to possess properties which would lead one to expect a quality of metal equal to the finest brands of Swedish, whilst anthracite possesses a high calorific power and enjoys a freedom from sulphur and ash, which should ensure its general adoption, both in the cupola and in the blast furnace. It has, however, been ascertained that with our present knowledge, peat cannot be successfully and economically employed, whilst with regard to anthracite coal it has the serious objection of readily breaking, both in handling and in heating, into what may almost be described as powder, and which is very difficult to burn, or otherwise deal with in the furnace. In the blast furnace this decrepitation is, as Mr. W. Hackney very truly stated in his paper read at the Manchester meeting of the Iron and Steel Institute, and published in the *Mining Journal*, of October 2, especially injurious, as the fine dust is apt to form together with the cinder pasty masses that can neither be melted nor burned away, and may choke the furnace up or seriously derange its working. These difficulties in the way of using anthracite generally, in its natural or raw state, have led to many attempts to make it into a serviceable coke, by coking it in admixture with a greater or less proportion of binding coal, pitch, or other bituminous substances. None of these attempts until very recently appear, however, to have been commercially successful; none, at least, of those made in South Wales have been carried out largely or continuously, as, though coherent coke was made, it was friable and of inferior quality.

But the great promise which anthracite coke gave of becoming a valuable metallurgical fuel, provided certain comparatively trifling objections could be overcome, was a sufficient inducement for inventors to labor on in the same direction; and at last, by the process of Messrs. Penrose and Richards, of Swansea, a hard and sound anthracite coke was successfully made on a working scale. So great has been the success of the process that the Landore Siemens Steel Company have now 120 ovens making anthracite coke; they use it and nothing else in their blast furnaces, with constantly improving results; they now make a ton of iron with less than a ton of coke. More recently the process has been tested, with highly satisfactory results for the manufacture of the anthracite coke, with the anthracite and anthracite culm, from Mr. F. H. Smith's Rhos Aman Collieries, near Swansea and Llanelly. The resulting coke was tried at the Three Counties Foundry, Cwm Twrch; and, with regard to its

behavior, Mr. John Thomas writes that after lighting and filling up the cupola they charged as follows:

	1.	2.	3.	4.	5.	6.	7.	
Pig iron and old railway chairs, cwts.	4	4	4	4	4	4	6	=30 cwts.
Coke, . . . lbs.	32	32	32	32	32	32	—	=192 lbs.

This completed the iron they had to cast, but if they had had more work to do they might have gone on at the same rate as long as the cupola would last in repair. The iron came out hotter than usual with them, and suitable for the finest castings, although the proportion of coke to the iron was less than half of what they use of the best ordinary coke from Bridgend, and his foreman was of opinion that they might have put in 5 cwts. of iron at a time instead of 4 cwts., with the same result, in which he agrees with him.

The Landore Siemens Steel Company have at the present time two blast furnaces at work, and using anthracite coke exclusively—one on hematite ore, 65 ft. high by 17 ft. "in the bosh"—one on spiegeleisen, 10 ft. lower. As the latter has been only a few days at work the following statistics given relate only to the former: The make of pig iron was 300 tons per week from the one furnace, to produce which nearly 2 tons of 50 per cent. ore, and 18 cwts. of anthracite coke to the ton of pig iron, are used. The same furnace, when using best Glamorgan coke, took 27 cwts. to the ton of iron produced, or 50 per cent. more than anthracite coke, the yield being as nearly as possible the same with both. The quality of the iron is also much the same, but less sulphur with the anthracite. The Landore Company have bituminous collieries of their own, but the quality of the coal not being so good as that from which the best Glamorgan coke is made, they required when using the coke from their own coal 32 cwts. to the ton of iron. With regard to the furnace on spiegeleisen which has, as before mentioned, only just commenced using anthracite coke, it can only be stated at present that they started with 33¼ per cent. more burden than they had been putting in Glamorgan coke, the result being perfectly satisfactory, and they have no doubt whatever that in a few days they will increase the burden to the same extent as the other furnace, their only reason for placing less, being the exercise of proper caution in starting. From the foregoing it appears evident that anthracite coke is 50 per cent. more valuable than best Glamorgan, so that if you take the cost of making the former at the outside estimate of 10 per cent. or 15 per cent. more

than the latter, there is plenty of margin. It is stated that some foundries in the neighborhood give the Landore Company 7s. or 8s. per ton more for what they can spare of anthracite coke than the price of best ordinary coke, and are glad to get it.

With regard to the commercial result to be anticipated from the manufacture of anthracite coke it would seem to be encouraging, but this will be more readily judged of by the consideration of the character of the process. The materials being thoroughly crushed and mixed in the proper proportions, the coking process is proceeded with. The ovens used are of the oblong shape generally employed in South Wales—15 ft. long, by 5 ft. 7 in. wide at the back, and 6 ft. 2 in. in front, 4 ft. 4 in. high, to the under side of the arch. Each oven is charged through a hole in the roof with about 4 tons of the crushed mixture; this is leveled by a rabble put in through the door at the end, and a small quantity of bituminous coal, sufficient to form a layer about 2 in. thick, is thrown in and spread uniformly over the surface. The oven is then lighted by throwing a few shovelfuls of hot embers on the charge immediately inside the door, and the coking is managed as in working an ordinary charge of bituminous coal. The object of covering the charge with a layer of bituminous coal is to prevent the burning away of the pitch, and its use appears to be essential for the production of a hard and strong coke. Ordinary slack, of the same quality as that in the mixture, is used for the covering; this is mostly very small, but is not especially crushed. Rather more than two charges per week are made in each oven; the coke is watered in the oven, and is then drawn out in one mass by a chain and hand winch. The yield of coke is 80 per cent. of the weight of the charge. The coke is steel gray in color, and very much harder than the anthracite from which it is made; so hard, indeed, that it scratches glass with comparative ease. In a common fire, or under the action of a blast, it burns away without showing any tendency to crumble or decrepitate. It is about 23 per cent. heavier than the best coke made from Welsh bituminous coal, so that in sending a cargo abroad recently a vessel that could not carry more than 240 tons of ordinary coke was able to take in as much as 310 tons of anthracite coke. Another valuable consequence of the dense compact character of the coke, in addition to the saving in cost of carriage, is that even if soaked in water it takes up very little, only from 1·5 to 2 per cent. of its weight, while many kinds of ordinary coke

absorb readily 10 per cent. or more. The saving of labor in charging the furnaces will also be considerable, as there only need be two-thirds by weight of the anthracite coke put into the furnace to do the same amount of smelting as ordinary coke, and the furnaces will yield a much greater quantity of pig iron. The coke is harder and more dense the finer the materials are crushed, and the more intimately they are mixed.

In carrying out the process the anthracite culm, slack, or coal, is disintegrated, and if containing earthy matter, or silica, pyrites, and such like, is well washed; it is then mixed in the proportion of anthracite small 60 per cent., bituminous small 35 per cent., coal tar pitch 5 per cent. = 100. One ton of this when converted into coke will yield 16 cwts. of best coke, or 80 per cent. Its property is that it is very hard, and will carry the iron well in the smelting furnace, saving thereby 27½ per cent., and in the cupola nearly 40 per cent., against ordinary South Wales coke. The cost of machinery and plant for disintegrating, washing, mixing, &c., for 150 tons a day will be about 1500*l.*, exclusive of ovens. A complete plant, including ovens (100) for turning out 100 tons per day, will cost about 8500*l.* The cost of preparation of 80 tons of coke per day will be:

Anthracite culm,	.	.	65	tons at	3s.	6d	.	.	£11 7 6
Bituminous slack,	.	.	35	"	4	6	.	.	7 17 6
Coal tar pitch,	.	.	5	"	35	0	.	.	8 15 0
Cost of disintegrating,	.		100	"	0	6	.	.	2 10 0
Cost of washing,	.	.	100	"	0	6	.	.	2 10 0
Superintendence, &c.,	.		100	"	0	6	.	.	2 10 0
Labor, including loading and drawing,	.	.	100	"	1	0	.	.	5 0 0
Total,	.	.	.	.	.	.	.	.	£40 10 0
Producing 80 tons of coke, or per ton,	.	.	.	.	.	.	.	.	£0 10 2
Interest, wear and tear and repairs of machinery, ovens, etc.,	.	.	.	.	.	.	.	.	0 1 6
Royalty to patentee,	.	.	.	.	.	.	.	.	0 0 6
Carriage of coke to Swansea, including wagon hire,	.								0 1 6
Total,	.	.	.	.	.	.	.	.	£0 13 8

Many thousands of tons of the anthracite coke have already been made, and it will, probably, be much more extensively made hereafter, for it is considered that the field for the application of any practical method of utilizing small anthracite is very great. The quantity

available in Wales and in America is almost unlimited, and very much of that raised is now unsalable, merely because it is too small to be used. In Pennsylvania, according to Mr. Bell, one-fifth to one-half of the material brought to the surface in the anthracite collieries is thus thrown aside, partly shale and stones, but chiefly small and dust coal, perfectly bright.

ON TURBINE WHEELS.

By Emile Geyelin.

[*Read before the Franklin Institute, March 5th*, 1876.]

The subject to which I would call your attention this evening, is that of *Turbines.*

Before defining the meaning of the word Turbine, allow me to say that "water," the element made use of, having a given weight, 62½ lbs. per cubic foot, becomes a source of power when that weight, owing to the topographical formation of the country, can reach a lower level; and that power, is proportionate to the quantity of water, in a given time, as well as to the height it is allowed to fall—power being the product of weight multiplied by velocity.

The means by which water is made to impart power, are, as you all know, water wheels (and I might add water engines), of which undershot, breast and overshot wheels form one class, and turbines form another; the distinguishing features of these wheels being, that whereas in the first class, the water is allowed to act more by its weight, in the turbine class, it is allowed to act more by the speed due to the fall under which it operates. The term turbine is derived from the Latin "*turbo, turbinis,*" *a whirl or top.* It would imply, and, in fact, I have seen it often stated, that it means water wheels turning on vertical axes; but it is not necessarily so, since they are, especially when brought to use under high falls, coupled together on a horizontal shaft, and in that position produce satisfactory results; in which case, the water being admitted in opposite directions, neutralizing the great pressure that would otherwise be exerted on the step.

A review of the development of the *turbine* is a most interesting one; but we do not find any gigantic strides, such as the introduc-

tion of the railroad and the telegraph has made in the first half of this century. Still we can admire the final results, and see that through the patient labor of years, step by step, man has learned to avail himself of nearly the whole of nature's power in water; and with such certainty, too, that the greatly accumulated force can be relied upon with the same confidence as the daily rising of the sun.

Thousands upon thousands of our fellow beings derive a livelihood through its agency, and its effect upon the wealth of a people can be read in the plainest of language by looking at New England to-day. Holyoke, Lowell, Lawrence, Manchester—those young giants whose wealth is wholly created by water power, as developed by turbines, are but a fraction of what New England has already accumulated from its vast resources. Large amounts lie yet dormant in her streams, to be called into usefulness by her future engineers and capitalists.

Let us now follow the gradual development of the water wheel; at best, we can but slightly touch a subject of which volumes may be profitably written.

FLUTTER AND UNDERSHOT WHEELS.

The most primitive structure, to be found in the backwoods, far from any human centres—the Flutter wheel—seems like the first seed. Water may be plenty, but the means are scant. The noise of the water as it splashes on the rudely shaped buckets, will attract you towards it. Most likely, in a picturesque spot, you will find it, perched on moss-grown rocks, a slender axle holding a frame, to which are secured a few plates. No formulæ laden with Sinus-Cosinus—cube root or other algebra—have given direction to its simple form. Shall we value it less? Let the tourist say, who, in the fragrant atmosphere of its surrounding pine and hemlock, has watched its unskilled efforts to shape a few boards. Near akin to the flutter wheel we have the undershot wheel; more pretentious in its fitting apron, whereby less gamboling of the water is allowed, as it comes dashing along. Look at the straight plates! Note how the water strikes them unprepared, to be left free a few moments later to continue its downward course! Are you surprised when told that one-third of the *vis viva* is all that these wheels develop? At this step science lends its help. First note how it bends the bucket, into flat surfaces at varying obtuse angles; then to the graceful curve of the "Poncelet wheel." Here are no sudden shocks;

the plates quietly receive the pressure, and like a kind friend, hold the water in their folds to the very last. As a consequence, as high as sixty per cent. of force of the water has been developed by these wheels. The undershot wheels are adapted to low falls, and specially where slow motion is required, such as for the purpose of forcing air or water; but even in these conditions the turbines gradually take their places.

OVERSHOT AND BREAST WHEELS.

Many, no doubt, can remember when no other kind of water wheels would have found approval; and this day, for a small varying stream, what can give better returns than the slow, patient overshot wheel, waiting for the water as it comes filling bucket after bucket, and turning round when ready with its well filled side? It is not in this puny capacity, however, that the merits of the overshot or breast wheel should be estimated. Years ago many a stately factory was propelled by them. But valuable as they are in their application to the falls varying from twelve to sixty feet, they have objectionable features which their rival, the turbine, has not; they are therefore fast losing ground.

Let us examine these objections. We have, for instance, the comparatively large size, especially where a large power is required in a concentrated form, such as the propelling of a large cotton or woolen mill. Again, the fact that for the most cases wood is employed in their construction, which renders them short-lived and liable to many stoppages and repairs, we have also the necessity of having them housed in winter to prevent the ice from forming on their buckets; and last, but not least, we have as an objection, the loss of power by friction, created by the changing of their slow motion to the high one of the main shaft, which in most mills amounts to an increase from ten to twenty fold. All these objections are common to both the breast and overshot wheels, but the breast wheel presents comparative advantages over the overshot, which renders the preference for the turbine over the former, less marked.

Take, for instance, a stream wherein the water level varies; the breast wheel, with the arrangement of gate, can adapt itself more readily than the overshot wheel. When the upper level falls say eighteen inches, it draws from the lower gate; whereas the overshot wheel, unless originally constructed with a pressure greater than

necessary in the ordinary stages of the stream, will not be able to receive as much water as needed, owing to the reduced pressure over the gate. Another advantage of the breast wheel is that the water, as it leaves the wheel, is forced away, whereas the water, as it leaves the overshot wheel, is, to some extent, drawn under—thus submerging the buckets to some extent. In the overshot wheel, also, much of the water leaves the wheel before the lower level is reached, and therefore its developed duty is proportionally lessened.

Though overshot and breast wheels are not to receive our special attention on this occasion, I have dwelt somewhat at length on their main features, so as to be better prepared to review the second class of water wheels, namely:

TURBINES.

How long water wheels revolving on vertical axes, or, to speak more properly, water wheels depending more on velocity than on gravity, have been in use, I am unable to say; it is quite certain, however, that fair specimens were left in Spain by the same people who left the Alhambra and other architectural wonders. Coming to more recent times, Belidor, the famous hydraulic engineer, a century and a half ago, in describing the fountains of Marly, amongst other kindred subjects, gives us descriptions and plans of water wheels belonging to this class.

Until the beginning of the present century, the record of advance made in the construction of turbines, is not worth stating; but the earlier years of the nineteenth century exhibit the fruit of patient labor, as shown in the Fourneyron turbine. This turbine was improved, both in detail and in efficiency, by two of New England's honored sons, Uriah H. Boyden and James B. Francis—the former of whom can be considered its introducer into the mills of the United States. The perfection of their work rendered possible the great accumulation of power, whereby so many human hives are enabled to labor with profit to themselves, and to change the rocky hills into green and enlightened homes.

To state that the Fourneyron turbine was the only one of any merit, even a quarter of a century ago, would not be correct, since formidable rivals, especially those offering the advantage of smaller cost, soon made their appearance, and year by year since, these new, or fancied new, applications of the water, turned up; until now, the turbine family is so large that its very names become bewildering.

In a theoretical point of view, matters become much more simple, since many of the turbine wheels known to the public are but combinations, and sometimes simply poor imitations of the parent stock.

For the purpose merely of tracing the analogy of the different kinds of turbines, I should like you to note that in the simplest form, a jet, and in more perfect forms, a series of jets, gradually prepare the water to strike the plates of the revolving wheel. It is in the perfection of the direction of these jets, and the corresponding area of a section of them to the area of the openings for discharge in the revolving wheel, that the main advantage of a turbine lies. The better class of turbines embody the principle of reaction, whereby an additional force is obtained.

The *Scroll*, *Reynolds*, *Trips* and *Parker* wheels illustrate the principle of a single jet. The water is led to the wheel through a contracted channel, and by increased velocity, strikes the plates of the revolving wheel. The Scroll, Reynolds and Trips, by the eccentric form of the casing, are able to act on the greater part of the periphery. The additional velocity to reach the extreme points, created by the contraction of the inlet, must always be obtained at the sacrifice of power; since the maximum effect of the water, can only be obtained when the full pressure due to the fall is brought into action at the first point of contact with the wheel which, must be so constructed and speeded that the water will leave the wheel with the minimum of velocity. The wheels above named, can *not* thus lay claim to high duty; from the simplicity of their construction, and espe cially where great economy of water is *not* necessary, they are much used. They are the pioneers to prepare the way for a more economical class of wheels to take their places.

Before speaking of the wheels where a series of jets are used in connection with the reaction principle, I would call your attention to the wheel acting *solely on the reaction principle.* In its primitive form it is known as *Barker's* wheel. A hollow, upright tube, through which the water is led to two arms, near the extremities, and on the sides of each arm are openings for the escape of the water; this simple construction comprises all the component parts of a Barker's wheel. A better form of this wheel, made with a closer application of hydraulic laws, becomes the "Scotch motor," in which the water is brought in an ample tube to two gradually diminishing and gracefully curved arms, whereby the water is allowed to retain much of

the pressure due to the difference of level under which it operates, and thus produce results which render it a most desirable motor; particularly where a constant changing of power is desired. The most successful application of that class of motors is at the Morris Canal, where they are used to propel the winding apparatus whereby canal boats are raised and lowered. Their construction is so plain that they proved most durable under quite unfavorable circumstances.

This reaction or retrograde force is thus the *additional* force whereby the highest returns of the water have been obtained. The first one to apply the double sources of power, *impact* and *reaction*, was Fourneyron.

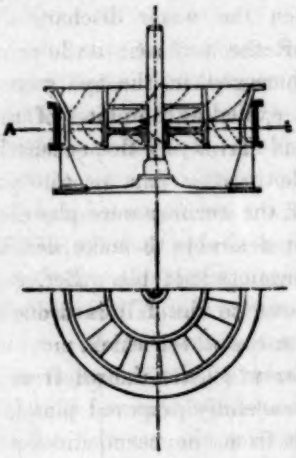

Fig. I.

The turbine represented on the screen (Fig. I) is an exact copy of one built by Fourneyron himself, 40 years ago; were I able to give you on the same screen the same class of turbines as constructed by Boyden & Francis, you could not avoid admiration for the thoroughness of their researches in finding, applying and perfecting of curves, and for the mechanical appliances, whereby the water is divided and prepared, from which curves and appliances were derived those astounding results (92 per cent.) of the total efficiency of the water power; that is of what power it would require to replace the water used in propulsion back again in the basin. Notice the avoidance of sudden change of direction of the water, which, you will observe, is brought in a spacious conduct, whereby no great velocity is created: Standard velocity being from 2 to 3 feet per minute, nearly all is saved for the time of action on the wheel; from the base it is led by well formed cylindrical curves, secured on a stationary disk, to the plates of the movable wheel: The angle at which the water leaves the guide plates is calculated to strike the plates as near the tangent as possible: The angle is in the best wheels from 14° to 15° to the tangent, which becomes the angle on which the force is applied: By a gradual contraction of the space between the plates of the revolving wheel, the water is brought to the point of discharge, which is so arranged as to direct its retrograding force so as to bring the resultant force at a still more

reduced angle to the tangent: Careful computations make the ratio of forces as 8 is to 2.

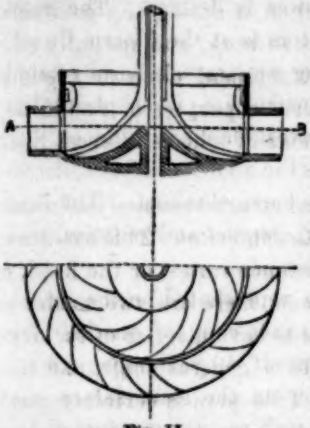

Fig. II.

In the year 1840, Jonval gave a new turbine to the world (Fig. II), which embodied a novel feature, in France at least, where it was invented, namely, the application of the vacuum. But a number of years previous, Zebulon Parker, in the State of Ohio, made practical applications of it in this country; he named it the draft tube. This draft tube is an air tight casing, in which the water discharges after it has left the turbine; its lower extremity is submerged in the tail race water and thus excluding the air. The practical effect is that a turbine provided with this draft tube can be placed between both levels that constitute the fall, and produce the same result as if the turbine were placed at the bottom of the fall. Where it is not desirable to make deep excavations, this application of draft tube becomes valuable. Before going any further, I would state that all downward and inward discharge turbines, invented since, are making use of this feature.

The action of the water is somewhat different in the Jonval from what it is in the Fourneyron. A series of carefully prepared plates prepare the water for action, by directing it from the perpendicular to an angle of 16° with the horizontal surface when it is brought in contact with the plates of the revolving wheel, which plates are so placed as to receive the entering water as favorably as it is received by a Fourneyron wheel, but, instead of the water discharging outward, in the Jonval turbine it discharges downward. As usual with all downward discharge wheels, the *Jonval* has the merit of compactness—and in connection with the fact of being able to place it in any position between the two levels, makes it a very desirable hydraulic motor.

Let us now pass in review the remainder of the turbines most favorably known. 1. The charts represent the Swain, the Liffel, (double), the Risdon, the American, and the Excelsior. All these wheels, either discharging inward or outward, make use of the double action of impact and reaction, and were they all constructed by the same mechanical engineer, very little difference would be found

in the return of power from any given fall and quantity of water. The principal cause of loss of efficiency is to be found in the want of proper mechanical and engineering skill in adapting any particular wheel to the conditions under which it is to work, and specially so is the operation of gate or gates wherewith to open, close or regulate the quantity of water to be used. For the purpose of facilitating the comparison, I have shown the sections of wheels in cross lines, and of the gate in solid blast.

When performing an equal duty with an invariable supply of water, the gate of a turbine is used merely to start and stop. This condition, however, seldom occurs. Either the resistance varies, or the head, or height of column, of the water varies; and there are two modes of overcoming these variations. The first is to have a series of turbines, sometimes of varying power, connected to a general shaft, and thus connect or detach a turbine as wanted. This plan is certainly good, but often for want of space, or with the view to simplicity and compactness, it is desired to obtain the same results with one turbine. The second mode is that of closing or opening the gate or gates, and thus regulate the supply of water to meet the variation of head or the variation of resistance, or the effect of both variations combined. It stands to reason that the turbine which retains the two elements of power in their greatest perfection, is the one that comes nearest to that desideratum of working the best results under the above named variations. The gate of the Fourneyron turbine, you will observe, is a ring closing between the guide and movable wheel. The effect of this gate on the stream of water must be bad, since it brings the water by an abrupt closure or stoppage, into a flat, thin sheet, which, after passing beyond the gate, is left free to enlarge in thickness, on its way to the outer periphery, with not enough pressure left to act upon the wheel. Of course it would be possible for the makers of the Fourneyron turbine to construct the outer, movable wheel in flat divisions, like a series of separate wheels, one upon another (in place of one wheel, as generally made), when each division of the wheel would only receive water as the gate is elevated; but this construction has not heretofore been used by them.

The *Swain turbine* (Fig. III), you will note, has a better gate than the Fourneyron, since it brings the water between flat surfaces in any position it is put, but it is subject to the same objection as the Fourneyron gate, in not proportionally closing the movable wheel.

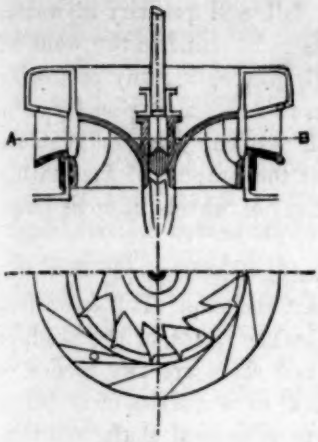

Fig. III.

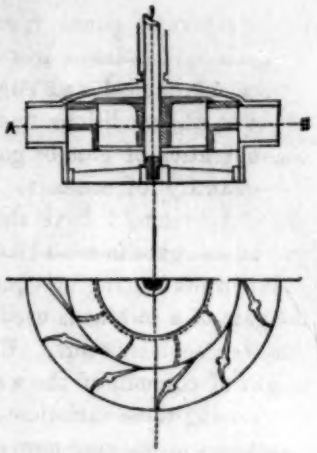

Fig. IV.

The *Liffel* wheel (Fig. IV) presents the same feature as the Swain, of directing the water between the flat, though contracted, passage ways to the point of action, but with it also a corresponding contraction is not established in the movable wheel. The same remarks may be applied to the American turbine (Fig. V), and the Excelsior (Fig. VI).

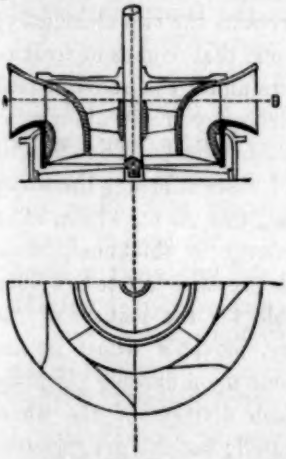

Fig. V.

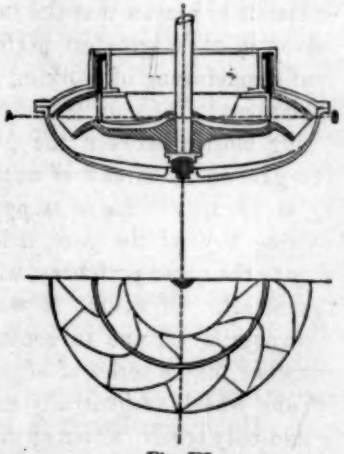

Fig. VI.

These conditions of imperfect action of the gate as usually applied to turbine wheels have led me to adopt a plan of gate for the Jonval turbine, which is here represented. It will be noticed, Fig. VII, that the division of the water, in halves or in thirds, is com-